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EVACUATION RESEARCH: A REASSESSMENT

by

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LIST OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

ASLB	Atomic Safety Licensing Board
CDC	Centers for Disease Control
CSEPP	Chemical Stockpile Emergency Preparedness Program
DOT	U.S. Department of Transportation
EBS	Emergency Broadcast System
EMO	emergency management officials
EOC	emergency operations center
EPA	Environmental Protection Agency
EPZ	emergency planning zone
FEMA	Federal Emergency Management Agency
GAO	U.S. General Accounting Office
IFWS	informative fire warning systems
LEPC	Local Emergency Planning Committee
NHC	National Hurricane Center
PRA	Probabilistic Risk Analysis
REP	Radiological Emergency Plan
SARA	Superfund Amendments and Reauthorization Act
SES	socioeconomic status
SLOSH	sea, lake, and overland surges from hurricanes
TMI	Three Mile Island

ABSTRACT

The purpose of the study is to examine the current literature on evacuation and to update a previously published annotated bibliography on evacuation issues (Vogt and Sorensen 1987) and research assessment (Sorensen et al. 1987). The objectives were to determine if concerns raised in the previous analysis of evacuation research were still valid in light of recent empirical research and theoretical findings and to determine the current trends and needs within the field.

The study identified and reviewed nearly 250 books, articles, reports, and papers on evacuation. Overall, it is evident from this study that we are experiencing a steady progression of knowledge about human behavior in evacuations and evacuation planning. It is also safe to conclude that no revolutionary new discoveries have been made. In some areas, the research is characterized by new insights on fairly specific issues, such as panic, but there has been no new research finding that would significantly challenge existing paradigms in disaster research.

1. INTRODUCTION

1.1 RESEARCH OBJECTIVES

This study was undertaken for the Federal Emergency Management Agency (FEMA) and the U. S. Department of Army in support of the Chemical Stockpile Emergency Preparedness Program (CSEPP). The purpose of the study is to examine the current literature on evacuation and to update a previously published annotated bibliography on evacuation issues (Vogt and Sorensen 1987) and research assessment (Sorensen et al. 1987)[1]. The objectives were to determine if concerns raised in the previous analysis of evacuation research were still valid in light of recent empirical research and theoretical findings and to determine the current trends and needs within the field. In keeping with the objectives of the CSEPP, we focused on emergencies generated by technological, chemical, and hazardous materials incidents. Empirical research is based on data gained from surveys, questionnaires, interviews, or a combination thereof and the use of secondary sources. Theoretical work summarizes past research or involves the development of conceptual models. The approach involved an extensive literature search and analysis of the issues generated from the current theoretical and empirical research agendas.

1.2 RESEARCH APPROACH

1.2.1 Research Expansion

Although this report continues to focus on verified observations and the subsequent theoretical implications of the findings for analysis of evacuation behavior and issues, we have broadened the research scope to include evacuation experiences as reported by emergency practitioners and first responders. In recent years, a number of trade and association publications have concentrated on specific aspects of evacuations intended for the emergency practitioner and planner. Most of the reports are directed toward the practical aspects of conducting evacuations and thereby lend an added dimension to the empirical documents.

Other features lacking in the general evacuation literature at the time of the original publication (Sorensen et al. 1987) involved evacuations of institutionalized and

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[1]This document updates J. Sorensen, B. Vogt, and D. Mileti, *Evacuation: An Assessment of Planned and Research*, ORNL-6376. It assumes the reader is familiar with the original report which is available from the author or FEMA.

special populations. We have made a concerted effort to include materials on these specialized segments of the public in this document for two reasons. First, the courts are inclined to address the issues of such groups in assigning liability. Second, some specialized populations are determined to share equally in public resources available to protect themselves in emergencies. Increasingly we have noted complaints about the inadequacy of evacuation shelters for the elderly or the disabled, whose requirements are different from other members of the general public.

Lastly, we have included some of the most recent work dealing with significant disasters in other countries. Probably one of the more significant aspects that evolved from the Chernobyl Nuclear Plant disaster was the increased attention of the international disaster and academic communities to compare measures of radiation doses and strategies designed to minimize harm from radiological releases. Such discussions include the determination of dispersal plumes, when to shelter or evacuate an exposed population, and the acknowledgment of the need to plan for the worst-case scenarios. The materials are not complete, but we include the documents to encourage analysis of cross-national issues.

1.2.2 Updating Planning Information

The purpose of this document is to update managers, planners, policy makers, and others related to the field of emergency planning on the current issues and thinking on evacuation behavior and planning. Protecting human lives by withdrawing populations during times of threat remains the essential evacuation management strategy. There have been some recorded instances wherein removal of property or livestock to safer places has been a major evacuation activity for some businesses such as automobile or boat dealers and farm managers, but this aspect of emergency activities lacks systematic validation. What has occurred in the past half decade is a greater focus on the varieties of subgroups that require attention from evacuation planners other than that normally given to the general public's needs. This trend may lead to better typologies away from the generic planning models and to more critical thinking about factors affecting evacuation planning and response.

1.2.3 Modeling Evacuation Behavior

Modeling evacuation rates and times remains a challenge for transportation engineers, evacuation planners, and emergency practitioners. The traditional

philosophy that persons evacuating would follow adequate warnings, along with specific directions, has been questioned as planners become more aware of the complexities of human response to threat. Thus proactive models have been developed that reflect evacuation of population as a process rather than as a single withdrawal activity. The significance of this type of modeling has been enhanced by the increased use of micro-computers and personal computers and by other communication equipment that is readily available to local officials and centers of emergency operations at a relatively low cost.

The portability of computerized information systems signals another level of evacuation planning that facilitates better coordination among emergency responders. Ideally, as communication increases, we may witness a more equitable distribution of resources among relief and emergency personnel, less confusion about specific responses to hazardous materials spills and radiological releases, and a decrease in re-entry problems. User-friendly, interactive machines that reduce repetitive tasks while increasing productivity may significantly change the role and responsibility of emergency officials. Computer models also enhance the possibility of developing corrective actions to adjust emergency plans or programs for future policy-making decisions. Projecting or simulating computerized plots and diagrams of exiting vehicles may decrease political arguments based not on empirical evidence but on outdated disaster myths of panic or flight behavior.

Furthermore, the models that have been developed suggest the possibility for greater coordination between state, federal, and local emergency managers and planners as data banks and specifications become more normative in the developing methodology. The data presently require specific instructions or techniques that may become less important as systems are modified for greater utilization by practitioners. Further incentives to decrease the difficulty of accessing such information may come from right-to-know legislation guaranteed under Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). Access to hazard data may also improve citizens' abilities to participate in decision making, especially when determining what plans or responses are appropriate for different threats.

1.2.4 Evacuation as a Planning Problem

In this text we use the term "evacuation" to describe the withdrawal actions of persons from a specific area because of a real or anticipated threat or hazard. The time period for the span of withdrawal is elastic in that the evacuation may last for any

amount of time. Thus, we include events when a return to the original site is not feasible or is forbidden. In this sense, we have deviated somewhat from other researchers, such as Quarantelli (1980), who argue that evacuation is a round-trip event. Given events such as Chernobyl, drought in the Sahel, Love canal, and sites made uninhabitable by chemical hazards or recurrent flooding, the decision to include long-term resettlement and relocation in the evacuation continuum of research appears appropriate. Long-term relocation or extended evacuation periods may signal yet another trend affecting issues related to evacuation research.

Although an evacuation occurs at least once a day in the United States, it is difficult to typify an everyday evacuation in a generic model. Evacuations lack both definition and consensus on specific parameters. An evacuation may be a precautionary measure action or may be instigated in rapid response to a manifested risk or hazard. Evacuations occur across a variety of time periods, impact various numbers of people or groups, and have both psychological and physical outcomes for those involved. This ambiguity distracts investigations of timing and modeling efforts and challenges the ingenuity of emergency managers and practitioners to respond efficiently. Disasters of human causation tend to affect more people than disasters of natural origin, primarily because of population distribution. The forced relocation of certain racial groups promoted at the institutional level, such as has occurred in the South Africa apartheid movements, frequently results in disaster both for evacuees and for the heads of states that can threaten the entire economic structure of the country involved (Clarke et al. 1989).

Although all populations suffer to a greater or lesser extent from numerous types of disasters, it is the nations with abundant resources that can afford to plan for disasters and institute mitigation measures to alleviate future threats. Ironically, these same countries do not suffer the frequency or hazardousness of events that devastate the poorer populations and their economies; thus, the poorer and less-developed countries bear the greatest burden from deaths, property damage, and environmental losses due to disasters and extended evacuation movements. The current methods of transporting hazardous technologies without the safeguards of regulations inherent in our own culture to other less-developed countries may further increase the vulnerability of those nations to more hazards, more disasters, and consequently more evacuations with even more serious impacts. The Bhopal tragedy, therefore, may not have been an anomaly, but a precursor of future tragedies.

1.2.5 Methodology

A number of methods were employed to procure the documents for the annotated bibliography to support the findings of the document. Both social science and hard science periodicals were examined for information. This procedure also included investigating trade journals and other materials prepared for emergencies or evacuation actions by commercial and industrial interests and trade organizations such as the National Fire Prevention Institute or the Chemical Manufacturer's Association. In addition to the literature survey, we conducted a computer search through selected DIALOG data bases of documents listing derivatives of the words evacuate, hazard, disaster, response, behavior, management, warning, and emergency. We also examined bibliographies from the available literature to determine if any references were appropriate; those that were applicable to the research were included. Finally, we examined a number of public documents and publications produced by the U. S. government, including those published by the Environmental Protection Agency (EPA), FEMA, the U.S. Department of Transportation (DOT), the Atomic Energy Commission, and the U. S. Army Nuclear and Chemical Agency.

1.2.6 Summary of Report

Section 2 examines the issues and summarizes key findings since the earlier assessment of evacuation research. Included in Sect. 2 are issues raised in point form and the associated documents related to the findings. The final chapter briefly summarizes the major conclusions and discusses the trends that appear evident from the documents. A bibliography of the literature reviewed is found in Appendix A. A companion document annotates those citations reviewed (Vogt 1991) and provides more complete information on the issues reviewed.

2. EVACUATION PLANNING ISSUES

2.1 INTRODUCTION

The grouping of topics in this section parallels the topics in Sects. 3 and 7 of the earlier assessment document (Sorensen et al. 1987). We have not attempted to repeat findings from the earlier assessment. Issues identified in the earlier work came from a variety of sources, including research reports, critiques of emergency planning, editorials, transcripts of hearings, litigations, manuscripts, and newspaper articles. Issues were summarized in point form for each hazard. A conceptual typology of major issues was induced from these lists. Major categories of issues and their definitions include:

- *Warning issues.* Characteristically, these issues reflect the nature of the information dissemination process. Topics include the ability to notify and provide a warning message, the quality of the information, and timing of the message delivery.

- *Social issues.* These issues center on the pre-emergency population attributes, including psychological, demographic, and social characteristics. How a threat or risk is perceived and whether a public has the ability to respond are often determined by existing conditions.

- *Organizational issues.* Included here are the attributes of emergency preparedness and response organizations. Whether plans are adequate, how training of emergency personnel takes place, and what constitutes the basis for evacuation planning are among the major questions.

- *Response issues.* These issues center on the behavior of people and organizations in responding to an emergency. Typically, concerns are raised about constraints to evacuation, possible aberrant or unsocial behavior, abandonment of worker roles in emergencies, and discussions of decision strategies on when to evacuate.

In addition, several new issues have been identified that did not emerge in the previous study. These topics reflect the greater attention to specific areas missing in evacuation planning. Issues raised concern how pets or other animals restrain evacuation responses, community attempts to assess and recover losses from

evacuation efforts, documentation of hazards resulting in evacuations, and greater attention to the timing of evacuation responses. Themes manifested in other research are also evident. These issues involve the media's influence, the increased use of expert systems, and whether prior experience provides better integration of evacuation planning into community overall planning and resource allocation.

2.2 WARNING ISSUES

2.2.1 Uncertainty in Ability to Alert

The following issues address the uncertainty in ability to alert populations at risk:

1. lack of warning systems;
2. timing of warnings;
3. warnings and information will be withheld;
4. inadequate organizational communication;
5. risks not revealed to warning organizations;
6. warnings will not be issued to certain groups, such as transient populations; and
7. siren systems cannot be heard.

2.2.1.1 Lack of Warning Systems

No warning system will reach every resident in a threatened area due to some inability to disseminate or receive and understand information (inebriation, drug use, deep sleep, etc.). Overall, warning systems, especially the hardware and administrative procedures, have improved. Criticism that warning systems are inadequate to inform the public to evacuate retains validity for many fast-moving or unpredictable events such as earthquakes or hazardous material accidents. Most communities do not have highly specialized warning systems. Moreover, civil defense siren systems are becoming antiquated.

Warning systems for building evacuation are improving. Applied work in fire prevention has eliminated many problems with smoke detection and exit behavior training. Safety features, such as places of refuge to be used by those unable to evacuate, are now designed in public structures.

Dedicated communications networks, hotlines, guides, manuals, and training seminars, prompted to a large degree by the chemical industry to provide information

and immediate response techniques for chemical emergencies, have improved warning systems. Such measures have promoted more effective, rapid decision making by public officials and helped to reduce delays in warnings caused by ambiguity or lack of data.

A variety of studies document the adoption of warning systems for an assortment of hazards. One of the major changes in flash-flood mitigation in the past decade is the increase in the number of communities implementing warning systems for floods (Gruntfest and Huber 1989, p. 279). Gruntfest and Huber (1989, p. 284) note that the early flood warning system implemented in Ventura County allowed ranchers to move equipment prior to major flooding in March 1983. Another study reviewing emergency evacuations (Hushon, Kelly, and Rubin 1989) found that the methods most often used for notification and warning were door-to-door warnings coupled with emergency vehicle public address systems and television or radio announcements. A survey of 18 early warning systems in the United States, developed to protect communities against flash floods and dam failures, revealed problems of unanticipated maintenance costs and malfunction of the systems' components, varying levels of local commitment to maintenance, and an under emphasis on response capacity of officials (Gruntfest and Huber 1989). The study also discovered a tendency for communities to rely on warning systems as a substitute for implementing unpopular political measures such as restricting use of floodplains. Among the benefits noted in the review of 18 communities were reduced loss of property; where the systems had been actually utilized, increased interagency, as well as interjurisdictional, cooperation; increased data collection from the available instruments; and less reliance on costly structural projects to reduce flood losses (Gruntfest and Huber 1989).

One report prepared for the Centers for Disease Control (CDC) (Duclos, Binder, and Reister 1989) on the 1987 Nanticoke, Pennsylvania, evacuation attributed the high compliance rate (98% of households evacuated) to the use of a nuclear power plant alert and notification system. Development of the system had promoted public awareness of the community emergency plan for evacuation in the case of an accidental release. Other factors that may have contributed to high compliance were warnings of individuals by officials, the ability of people to see the fires, and the time of day.

A study of community preparedness for chemical hazards conducted by EPA looked at the type of warning systems used by communities with hazardous materials industries (Sorensen and Rogers 1988). Warning systems were classified into three basic types: enhanced systems, siren-based systems, and ad hoc systems. Enhanced systems use sirens and some form of specialized alerting such as tone-alert radios.

Siren-based systems rely on sirens for an alert, along with use of media-based notification. Ad hoc systems generally rely on media reports, an Emergency Broadcasting System (EBS), and door-to-door or route alert. The study found that the predominant means to warn people in close proximity of the chemical facilities is usually by an ad hoc method (45%). Sixteen percent rely on route alert or door-to-door notification. Another 29% rely on EBS or media warnings. Siren-based systems are utilized in 33% of the communities. Only 12% of communities have access to an advanced system involving both sirens and tone-alert radios for notification.

2.2.1.2 Timing of Warnings

Overall, we have gained additional insight into timing of warnings. Much of this knowledge has been derived from contentions over warning systems for nuclear power plants, primarily due to Atomic Safety Licensing Board (ASLB) rulings. The most significant debate on what constitutes a state-of-the-art alert/notification system came in an ASLB proceeding on the Shearon Harris Nuclear Power Plant. In their final decision, the ASLB defined what constitutes "essentially 100% notification within 15 minutes in the first 5 miles of the Harris Emergency Planning Zone" (23 NRC 294, 1986). The board required the utility to prove that more than 95% of the people within 5 miles of the facility would receive a warning in summer nighttime conditions, one of the most difficult warning times. The utility could not do so by relying solely on a siren system. To exceed the 95% requirement, commercial tone alert radios were proposed for all households within the 5-mile radius. The ASLB accepted this plan as exceeding 95% notification.

The basic logic behind the ruling was as follows. The board accepted a method for calculating sleep arousal by sirens. In this method, a sound level in a bedroom is calculated based on the attenuation of sound from outside to inside. The method assumed four 3-minute siren soundings. The probability of arousal for an individual was calculated at 62%. Household size was taken into account; it was assumed that one person older than 12 years hearing the sirens would wake others in the house. Based on the household size distribution, it was calculated that 83.5% of the households would be alerted. An additional 1% of the households not alerted would have someone awake at the time of the sounding, resulting in 84.5% alerting. It was assumed that those hearing the sirens would seek additional information.

The board, based on evidence from other disasters, accepted that 50% of the households would contact someone else after receiving the warning; thus, they held

that 42.5% would notify another household. Since 15.5% of the households had not been warned, an additional 6.7% would be warned, for a total of 91% notification. It was assumed that a route alert would not be feasible in a 15-minute warning period.

Under the proposal to use tone alert radios, the board accepted that 83% of the households would receive an alert from a tone alert radio. This was based on the experience within the Ft. St. Vrain Nuclear Power Plant in Colorado, which uses tone alert radios and one siren in their 5-mile emergency planning zone (EPZ). The ASLB concluded that of the 9% not hearing a warning, 7.5% would hear a tone alert radio, raising the alert rate to 98.5%.

The major problem in this hearing was the lack of distinction and the confusion over alert versus notification. The calculation of the 84.5% arousal by siren refers to the alert function only. At no time was the rate for the alert component of the siren system calculated. The informal and tone alert rates implicitly refer to both the alert and notification components, although with informal notification methods officials have no control over the message contents.

Expedient warning remains a thorny problem for emergency managers. As Rogers and Sorensen (1989) point out from their research into chemical accidents, some fast-moving events can provide no warning time for victims. They conclude that new warning technologies are needed for rapid warning dissemination.

Warning residents via telephone has limited capacity—only one telephone call can be made at a time. Advances in telephone systems may make "broadcast" calls available to numerous residents at one time. This type of system would be particularly advantageous for nighttime situations or for swiftly moving events with extremely short lead times. Note, however, that officials generally wait for confirmation before issuing warnings—time that is not always available to avoid threat.

Data collected at the Nanticoke, Pennsylvania, evacuation allow the first construction of empirically derived diffusion curves for different warning technologies. The curves show the cumulative percent of the population receiving the first warning over time by the four major methods of warning, which are shown in Fig. 1. The timing of the diffusion is very similar for sirens, route alerts, and informal alerting. Some of the early reportings of sirens and route alerts were likely people hearing emergency vehicles responding to the fire. The curves show a steep increase in notification when the official warning activity ensued. By 15 minutes into the official warning, data indicate that about 65% of the public had been notified. About 22% of the public had received a siren warning at this point. The remainder had received an informal warning from route alert or media.

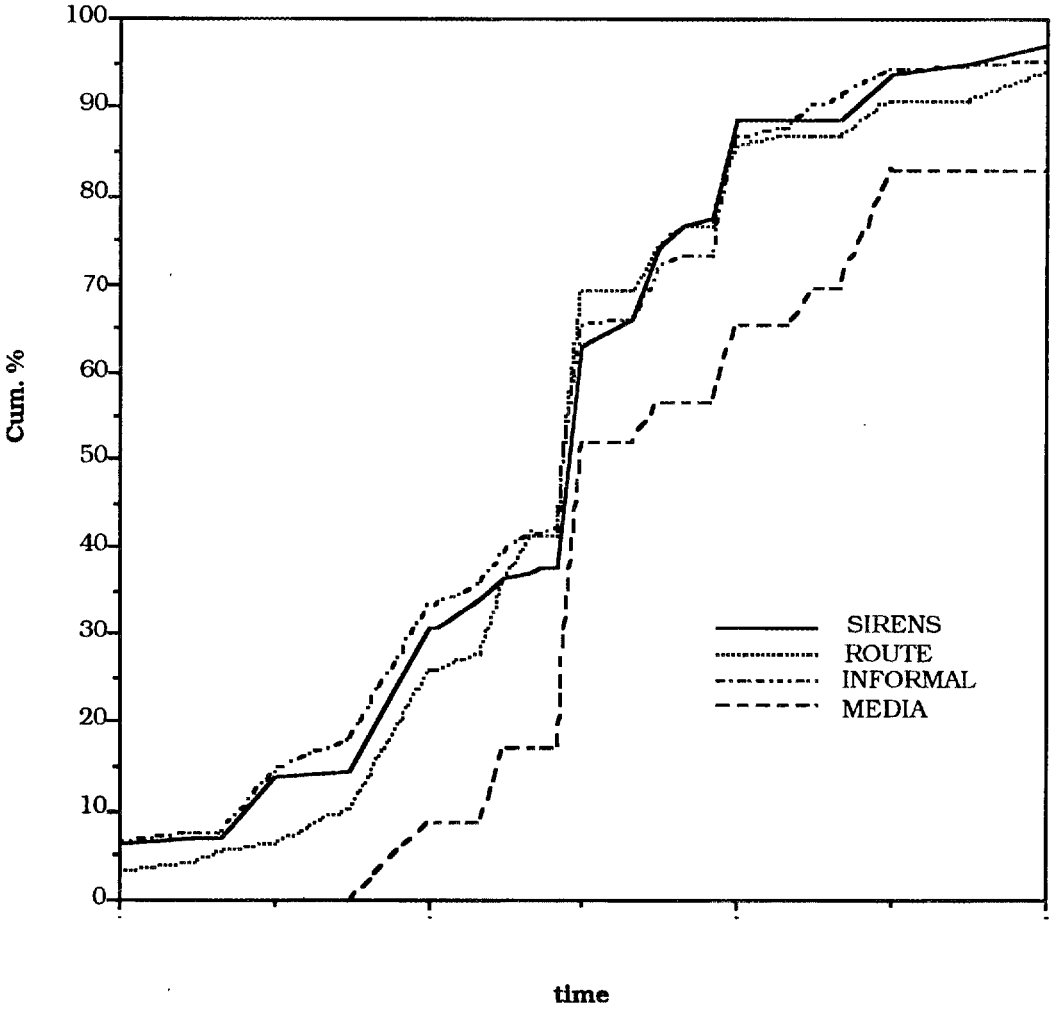


Fig. 1. Warning diffusion by source.

2.2.1.3 Warnings and Information Will Be Withheld

Research indicates there is not a problem with withholding information from the affected public. We found documentation of only two instances where information was withheld from the affected public. In these cases, two schools located near a chemical plant were not alerted when the plant accidentally released toxic chemicals (Abrams 1986). Public uproar over these cases resulted in an official investigation by the state's attorney general and new legislation being proposed regarding chemical releases.

In part, the move toward greater disclosure may be because of increasing liability concerns, media overreaction to past actions, or increasing community awareness because of the SARAs provisions on right-to-know. Reviewing common law obligations of manufacturers, suppliers, and the enhanced public regulatory efforts on right-to-know legislation, Green (1989) found a confluence of trends in toxic risk communication between the common law obligations of those responsible for hazardous and toxic substances to provide information, warnings and instructions about the substance and the enhanced public regulatory efforts to have information provided to affected employees and communities. Green notes that the scope of obligation to provide information about safe use and dangers is central to current litigation over risk communication and indicates a clear trend to provide more specific warnings about risks. The Occupational Safety and Health Administration Act also broadens the statute of limitations regarding warnings, with a retroactive provision to December 11, 1980. The broadening of information required from employers has increased awareness by more affected parties about substances to which they may have been exposed. Additionally, the data could provide additional ammunition to plaintiffs and communities by improving evidence in demonstrating causation. Current trends are likely to produce more, rather than less, obligations of risk-givers to communicate risk in the future. The adoption of the Hazard Communication Standard and SARA's Title III has likely improved the storehouse of knowledge about causal capacities of toxic agents, thereby providing greater information about toxins to victims and ameliorating barriers to suit. Adverse publicity and the potential for community opposition and activism from Title III disclosures may also provide greater incentives to companies to reduce exposures than will potential tort liability.

Provisions for warnings about events with ambiguous time-frames continue to receive criticism. Some anecdotal observations suggest that residents in hurricane-threatened areas have been "over-warned" by media anxious to retain listener ratings. Others observe that many hazardous material evacuations have occurred more as precaution against future liability than for an existing or potential threat. One study of the Nanticoke, Pennsylvania, metal processing plant fire questioned whether people would have suffered fewer adverse health effects from staying inside during the crisis than from evacuating (Duclos, Binder, and Reister 1989). The report suggests that mass evacuation may generate more problems in terms of health care and other services than remaining in place or sheltering.

2.2.1.4 Inadequate Organizational Communication

Exercises, including table-top types and computer simulation, have improved inter-organizational effectiveness in coordinating emergency response. Some exercises mandated by FEMA provide funds that promote compliance with exercise statutes. Trade journals among emergency planners and practitioners have further increased awareness of the value of emergency preparedness through exercises. Improved communication hardware is also more accessible and less costly to emergency organizations.

Research has attempted to document how organizational communications have failed in evacuations (Sorensen and Mileti 1987). Communication breakdowns that caused problems for effective evacuation decisions resulted from both physical communication equipment failures and human communication problems. In approximately half of the evacuations, equipment failure was a cause of poor communication. In many of the evacuations, problems were attributable to human factors as well.

2.2.1.5 Risks Not Revealed to Warning Organizations

The chemical industry has generally been reluctant to reveal potential risks to emergency officials. Evidence from the two Middleport, New York, toxic materials spills (Abrams 1986) indicates that industries chiefly respond to community pressure when it is applied directly to their organizations. In Middleport, compliance on warning nearby schools was accomplished only after the second toxic spill occurred and was not reported to school officials. High-school students staged a sit-in demonstration that resulted in better compliance from the chemical company in relaying promptly to the nearby schools information on all toxic spills.

We have gained better understanding of who will provide or withhold risk information. Hazardous materials managers more likely to withhold information are associated with smaller, rural companies, whereas managers of the larger conglomerates are more likely to act responsibly (Sorensen and Rogers 1988). Similar findings come from research on the implementation of SARA Title III community right-to-know mandates.

Using the Woburn, Massachusetts, community response to a toxic-waste-induced disease as a case study, Brown (1987) found that environmental activist groups using popular epidemiology techniques can force public officials to take action. Popular

epidemiology in Woburn was the major impetus to re-establishing the state's cancer registry, for passing a Massachusetts's law to monitor toxic wastes in water supplies, and to spur other communities to demand fuller investigations and disclosures of environmental risks. The activities of the groups increased research by the Department of Public Health in Woburn and eventually led to shifts in EPA practices in detection and management. Environmental health hazards have traditionally been identified and controlled by two sources—scientific research and government regulation—but environmental activism in the past decade has made community groups a potential third force in political action (Brown 1987).

2.2.1.6 Warnings Will Not Be Issued to Certain Groups

Research has provided additional insights on the issue of warning transient populations. Some evidence indicates that transient populations are receiving more attention from building designers and emergency planners (Pauls 1987; Sato and Ouchi 1986). An evacuation model, developed by Technica, that simulates evacuation times in Europe for radionuclide releases from nuclear power plants includes estimations of transient population numbers in the methodology (Bellamy and Harrison 1988).

Jacobs and 't Hart investigated disasters in recreational centers such as the Hillsborough Stadium in England, where 95 spectators were killed while attempting to evacuate from a surge of people into an over-crowded stadium. Comparing the tragedy in England to the one at Heizel Stadium in Belgium, in which 39 spectators were killed, the authors conclude that factors such as lack of communication and inter-organizational ambiguity created similar instances for acute stress.

Johnson and Johnson (1989) investigated factors leading to the 1977 tragedy at the Beverly Hills Supper Club fire in Kentucky. Examining employee behavior led researchers to suggest that all persons engaged in pro-active social behavior but that proper training of employees in emergency procedures would have facilitated the evacuation and decreased the mortality rate.

Bryan's (1982) empirical study of behavior in the MGM Hotel fire in Las Vegas, Nevada, in November 1980 provides the most comprehensive analysis so far on transient guest's behavior in an emergency. Supported by the National Fire Protection Association, this study examined the times and means by which hotel guests became aware of the fire and the first five actions taken after discovery of the fire. Initial actions taken were to prepare to evacuate (get dressed), obtain information on the fire threat, and alert others. Although the fire killed 85 people, the only indications of non-adaptive

behavior observed or indicated by the study population concerned initial behavior on the roof among evacuees trying to escape via the first helicopter rescue and the death of 2 guests who jumped or fell from the north side of the hotel. The findings on evacuation behavior include:

- Evacuation routes: 78% of respondents used stairs to evacuate the building.
- First actions of guests: actions varied according to whether the respondent was alone or with others and by physical location in the hotel.
- Evacuation status of respondents: 19.3% stayed in their rooms, 43.3% evacuated successfully, and 37.3% attempted evacuation but did not succeed and had to return to their rooms or to other rooms to take refuge.
- Awareness of fire: 49% of the respondents were aware of the fire before the fire department received the initial alarm at 7:17 a.m.

2.2.1.7 Siren Systems Cannot Be Heard

Because of investigations on the Nanticoke evacuations, we have a great deal more information on siren efficacy. In discussing siren efficacy, one must distinguish between fixed and moving sirens such as those on police cars. A fixed siren system is less effective than earlier assumptions made by emergency managers. Habituation to sirens (and thus loss of effectiveness in response in emergencies) result from sirens at factories, malfunctioning systems, etc. Route-sirens appear effective in facilitating late night response. The CDC survey of Nanticoke residents described ways in which people were warned to evacuate. These warnings included sirens, officials going through the streets with loudspeakers, officials going door-to-door, friends or relatives going to someone's door, telephone calls from friends or relatives, radio, and television. These are all common means used to warn people in emergencies (Lindell and Perry 1987; Sorensen and Mileti 1989).

Perhaps the most significant aspect of the warning is that the city of Nanticoke is within the 10-mile EPZ for the Susquehanna Nuclear Power Plant. As a result, the town is blanketed with coverage by the sirens that would be used to alert the public to a potential emergency at the plant. On July 30, 1986, a test of the sirens was made at 11:55 a.m. and a telephone survey was conducted to determine how many people heard the sirens. Results indicate that 76.5% of those polled heard the sirens. No data are available on the warning rate within the city of Nanticoke, but there is no reason to believe it would be significantly different.

Table 1 presents survey data regarding how people of Nanticoke first learned of the need to evacuate, which is the notification aspect of the warning process. It also presents the average time at which people said they first were warned. Sirens effectively notified about one-third of the sample. Informal notification was the major means of notification, with about 40% hearing from a friend or relative in person or over the phone. The media—not unexpectedly, given the time of day the event occurred—contributed to only 5% of the initial warning source. Officials going door-to-door or with loudspeakers accounted for 20.5% of the notification.

Table 1. Source and mean time of first warning

System	Percent warned*	Mean time warned
Sirens	34.1%	2:30 a.m.
Route: loudspeakers	15.7%	2:45 a.m.
Route: door	4.8%	2:14 a.m.
Informal: door	18.6%	2:24 a.m.
Informal: telephone	21.5%	2:37 a.m.
Media (radio or television)	5.2%	3:21 a.m.

*As percent of sample responding to the question with missing values excluded.

Comparisons of mean warning times indicate that notification through media outlets resulted in significantly slower times than other means of warning the public. Door-to-door warnings provided the earliest notification on average, while loudspeakers were somewhat slower. The other forms fall in between but are not substantially different from one another.

Surveys such as the one at Nanticoke are conducted to determine the effectiveness of siren systems at all nuclear power plants. The U.S. General Accounting Office (GAO 1987) documented that in these tests, 95.6% of sirens functioned at all times, and an average 83.1% of respondents heard an alert when sirens were tested. The same report, however, in reviewing the history of FEMA's activities to examine public knowledge about radiological emergency response, concluded that FEMA failed to include an assessment of public knowledge about what to do when a siren sounds.

Research on the dissemination of warning information and response conducted in two communities affected by derailment of trains carrying toxic chemicals in western Pennsylvania—Pittsburgh and Confluence—suggests that under conditions of rapid emergency onset, people may be engulfed in danger before receiving a warning, while others may have limited time to implement protective actions (Rogers and Sorensen 1989). The organizational decision to warn is critical to warning system effectiveness,

especially when available warning time is limited. To the extent that empirical results from the Pittsburgh and Confluence studies reflect maximum capacity to respond, the findings indicate that emergency systems based on portable sirens and low speakers are inadequate to provide effective warnings for extremely fast moving events.

Baron, Etzel, and Sanderson (1988) studied the health effects from the accidental chemical release at Institute, West Virginia, in August 1985 that resulted in 136 people being treated in 5 local hospital emergency rooms. Warnings of the toxic release were announced over radio and television bulletins, and a siren sounded at the plant, but no evacuation was advised. Only 5% of all treated victims and 5% of the community respondents heard the plant siren, while 7% of residents affected by the fumes prior to 10:15 a.m. heard the plant siren. Furthermore, no evacuation plan had been disseminated, nor had evacuation routes been established before the chemical release. The study found that 45% of victims presenting to emergency rooms learned of the release by detecting an unusual odor, 45% from media or word-of-mouth from others, and 5% by observing the vapor cloud in vicinity of plant. The combined evidence suggests that sirens as a warning source remain problematic.

2.2.2 Information Constrains Evacuation

Critics cite the following issues as constraints to evacuation response:

1. people do not understand a warning's special terms,
2. probabilities are not understood or are misinterpreted,
3. multiple messages create confusion,
4. warning content is inadequate,
5. warning credibility,
6. frequency of information, and
7. people do not understand sirens.

2.2.2.1 People Do Not Understand A Warning's Special Terms

Previous findings suggest that clarity and specificity in warnings lead to greater evacuation response and that the public does not remember special warning terminology. Subsequent research has not changed this conclusion. What has been confirmed is the inability of the public (and the media) to comprehend technical terms relating to radiological releases (Sorensen and Mileti 1989).

2.2.2.2 Probabilities Are Not Understood or Are Misinterpreted

Current analyses do not differ greatly about how the public's interpretation of probabilistic information affects evacuation response. One issue has surfaced about how the public's understanding of Probabilistic Risk Analysis (PRA) is influenced by local news media representatives. Some researchers have pointed out that not all media weather forecasters are trained meteorologists who understand the basic concepts regarding PRA. Thus misinformation on PRA can be generated to emergency managers who use local weather forecasts to respond to threats and influence the general public, who may regard the information presented by local forecasters as credible sources.

2.2.2.3 Multiple Messages Create Confusion

It still holds true that multiple messages create confusion. Methods to improve message transmission through cooperation with the media and designating staff positions for media and public relations in the Emergency Operations Center (EOC) have been found useful to emergency personnel in streamlining public messages. Successful evacuation during a fire often depends on the use of a public address system capable of delivering clear, audible messages and that maintains communication between fire control personnel and evacuees (Khisty 1985). One of the most current and vexing problems is how officials can transmit consistent, accurate messages on return times to evacuees, especially those residents not in public shelters.

Some risk communication studies suggest that the media strongly influences public perception of risks from both technological and natural hazards. Lichtenberg and MacLean (1988) studied the media's role in risk communication through a comprehensive review of previous research and case studies. They found that because people process positive and negative information differently, expecting an adequately and accurately delivered communication to suffice in achieving consensus on risk issues was unreasonable.

Some evidence suggests that a gap exists between the content of news coverage and public perceptions and understanding of risk issues, with the media constituting the source of much if not most of the public's information about risks and technologies. Where risk issues are embroiled in social and political controversies, those controversies themselves form an essential part of the "reality" that the news media must cover.

Lichtenberg and MacLean (1988) note that media outlets do not convey an accurate picture of reality and that this new portrayal of reality by the media leads to a fundamental change in the public's views. The increase in press coverage of an event contributes to intensifying the sense of danger, even if the coverage is not particularly negative. They found that most people rely on a few heuristics, or rules of thumb, in estimating risks or probabilities and are concerned not only about the magnitude of risks but also about other qualities, adopting a reference point from which outcomes or choices are seen as positive or negative. This reference point is influenced by how the choice is presented or described by people more receptive to negative than positive information in the press. Lichtenberg and MacLean (1988) suggest that the most important reason behind the inadequacy of risk communication is that risks are judged against criteria that are inappropriate.

The mission of the National Hurricane Center (NHC), in association with the National Weather Service, is to provide accurate and timely information on all hurricane threats, often through direct contact with state and local government decision makers and officials. This allows emergency personnel to determine what areas will be flooded and what evacuation routes can be used safely. However, it is also the NHC's practice to minimize overwarning during the forecast process. During Hurricane Gilbert, a private weather service company issued conflicting information concerning the forecast track of the hurricane that caused evacuation decisions to be made in the Galveston area (Grice, Sheets, and Perry 1989).

2.2.2.4 Warning Content Is Inadequate

Research indicates that the visual display of information is important in stimulating warning response. Experimental work in response to fire warnings has shown that combining display and message components of informative fire warning systems (IFWSs) enhances evacuation from buildings (Geyer et al. 1988). Geyer et al. (1988) found that using IFWSs increases evacuation rates five fold.

Research indicates that warnings have become more comprehensive in reaching special populations. For example, the research of Nober et al. (1990) on smoke alarms for the hearing impaired found significant increases in response through the use of strobe light alert systems. Although warning content has improved, advances have not extended to expanding egress routes in emergency evacuations. As more people with physical impairments move into the public domain, there is additional concern about

extending warnings noting specialized places of shelter during evacuations until rescue can occur.

Finally, research indicates that warning messages typically provide insufficient information. The attitude that people are incapable of processing information has led to a mindset that messages have to be extremely simple. This is erroneous. People demand a large amount of information in emergencies. If people do not receive information from official sources, they will seek other sources. In fact, providing too little information delays evacuation because people spend time seeking additional information (Sorensen and Mileti 1989).

2.2.2.5 Warning Credibility

Credibility is a central factor in whether or not people respond to a warning. We now understand, however, that credibility is a much more complex issue than many researchers have previously treated the concept. Both the psychological characteristics of the receiver and those of the warning entity are involved. Confusion is exacerbated when researchers misconstrue the differences between credibility of source versus that of channels. The interface and linkages between the media as a channel and the media as a source need further examination. Fischer (1989) has been particularly critical of how national media outlets "stage" material during television segments on storms such as Hurricane Gilbert. Similarly people as individuals have different levels of credibility than do the organizations they may represent.

2.2.2.6 Frequency of Information

The basic notion that people need frequent information in an emergency remains unchallenged. During extended warning periods, people want to receive as much information as possible. Empirical studies on hurricanes by Ledingham and Walters (1989) asked questions about the media's role in disseminating information about hurricanes. The authors found that the warning messages triggered the formation of a kind of hurricane culture where residents turned from the media to more personal communication channels while maintaining environmental surveillance through the media. The media and interpersonal channels of communication serve complimentary roles, each acting, at different times, as a prelude or as a support for the other while fulfilling unique roles. The results of studies of Hurricane Alicia and Danny support other conclusions: that media serves as the pervasive first source of disaster warnings

and that media, particularly television, serves as a surveillance function. Furthermore, the media enjoyed reasonable credibility for ability to forecast and report news in general and as a major source of information on how to prepare for storms. Although media alerted the population and provided information on response options, discussions with friends and family were equally important in the options respondents ultimately chose.

2.2.2.7 People Do Not Understand Sirens

New research helps us understand when sirens do and do not work. Evidence suggests that sirens do not always provide reliable warnings at nighttime or when a population is habituated to hearing them (Sorensen and Mileti 1989).

2.3 SOCIAL ISSUES

2.3.1 Social Factors Color Risk Perception

The major concern is that pre-emergency risk perceptions affect human evacuation behavior in responding to an emergency. Such concerns include the following:

1. mitigation gives a false sense of security,
2. previous experience,
3. depersonalization of threat,
4. fear of radiation,
5. denial of hazard existence,
6. lack of preparedness, and
7. false alarms.

2.3.1.1 Mitigation Gives a False Sense of Security

General findings that people's belief in mitigative structures, such as a dam or seawall, gives them a sense of false security remain true. How long or strongly this sense of security prevails when authorities order an evacuation is unclear. Further behavioral research is needed to address this problem that leads to noncompliance.

2.3.1.2 Previous Experience

Experience with a previous evacuation may affect future plans for evacuation, but reasons for not evacuating remain unclear. More evidence was gained from researchers studying Hurricanes Elena and Kate on how prior experience influences future decisions to evacuate. Hurricane Kate caused an evacuation of the Tampa Bay area about four months after Hurricane Elena prompted an evacuation that was not really needed. Baker (1987) found that evacuation rates in the Tampa Bay area for Hurricane Kate were similar to that for Elena, despite the earlier false alarm.

In a Japanese study on evacuation behavior because of fires, Kagawa, Kose, and Morishita (1986) found that previous experience with a bomb threat had no effect on residents' attitudes toward the need for evacuation drills. The general knowledge of evacuation procedures depended on how long the employee had been in the building and the designated role the employee held during an emergency, suggesting that emergency preparedness training could be as useful as experience.

Gray and Quarantelli (1985) found that past experience with hazardous chemical emergencies will likely influence the assessments of first responders to hazardous materials accidents. Scanlon's (1990) research indicates that previous experience does not make a mayor become interested in emergency preparedness or planning. In a survey of emergency professionals, Kartez and Lindell (1987) found that jurisdictions with the most experience tended to have effective planning structures and to have adopted good practices. Occasionally, people may imagine that an impending event will occur like those previously experienced, no matter what the current information suggests. Acting only on experiential data could impair judgments on evacuation (Mileti et al. 1985) or other mitigation strategies such as occurred during the Dutch hostage taking (Rosenthal et al. 1989).

2.3.1.3 Depersonalization of Threat

Acknowledging the danger exists but that it is not personally affective is called depersonalization. Findings from studies of Hurricane Elena suggest that this attitude exists in hurricane-prone areas. The sample by Nelson et al. (1988) of 2,820 respondents, of whom 1,802 lived in hurricane evacuation zones, showed that only 765 respondents (less than half) evacuated.

2.3.1.4 Fear of Radiation

No new research has been found to that indicate people will panic or move en masse when learning of a radionuclide release. Certainly, anecdotal evidence from the Chernobyl experience indicated that mass panic and hysteria did not take place. Some research suggests that fear of radiological accidents has stymied plans for building nuclear power plants, but the evidence is inconclusive, given other reasons such as disposal of waste and cost of construction.

2.3.1.5 Denial of Hazard Existence

Research continues to support findings that people deny a hazard exists when an evacuation is needed, especially when people are accustomed to the hazard's existence. Evacuation rates rarely approach 100%. How to overcome the reluctance to evacuate continues to be a problem.

2.3.1.6 Lack of Preparedness

No new studies have emerged that provide empirical evidence on the relationship between the level of preparedness and the efficiency of evacuation. The NUMARK study (Hushan, Kelly, and Rubin 1989) attempted to examine this issue, but problems in the research design and the type of data collected prevented empirical testing. Gray and Quarantelli's (1985) review of hazardous chemical responses found that smaller communities, with fewer resources and who depended mainly on volunteer services, were less prepared to respond to hazardous materials accidents than larger communities with trained personnel.

Bolton (1987) compared the various strategies used in school earthquake education and safety, and the community outreach programs for three projects. The research indicated that messages on hazards disseminated through many different channels at once effectively gained attention and interest. Furthermore, the combination of earthquake science and safety protective actions in one program reduced earthquake anxiety among school children.

Sorensen and Rogers (1988) studied community preparedness for chemical accidents in a national sample of communities. They found that management practices and procedures vary by site. Most locations have some type of emergency plan. Fewer

than 50% of the communities studied had clearly defined procedures for receiving an alert, making a decision to warn, and making a protective action recommendation.

2.3.1.7 False Alarms

The effectiveness of people's responses to warnings is not always diminished by what is labeled the "cry-wolf" syndrome. Two issues regarding false alarms are significant. The first concerns a false alarm that led to public response such as an evacuation. In this case, if the bases and reasons for the "miss" are told to the public and are understood by them, the integrity of the system will be preserved. Data from hurricane evacuation studies indicate that false alarms do not prevent people from evacuating in the future if they know the basis for the uncertainty and the false alarm (Baker 1987).

The second issue concerns repeated activation of the alert mechanisms. If such false alarms occur and no attempt is made to explain why, there could be a negative effect on subsequent public response to a warning of a subsequent event (Breznitz 1984). This is particularly true of inadvertent sounding of sirens if such malfunctions are frequent.

2.3.2 Factors Color Ability to Receive Warnings

Issues concerning the ability to receive warnings include:

1. culture and ethnicity,
2. disbelief in the ability to detect or predict, and
3. lack of understanding of hazardousness.

2.3.2.1 Culture and Ethnicity

We have accumulated more empirical research on how ethnicity affects evacuation behavior, but the new work does not change the basic findings (Perry 1987; Perry and Mushkatel 1986). Culturally diverse groups within a majority group are less apt to follow the dictates of the majority officials. For some minority groups, lack of resources may prevent people from evacuating, while other groups require interpretation of warning messages to understand the hazard.

2.3.2.2 Disbelief in the Ability To Detect or Predict

We found no new evidence to suggest that disbelief in the ability to detect or predict a threat or hazard hinders evacuation propensity.

2.3.2.3 Lack of Understanding of Hazardousness

Findings that people do not understand the risks from some hazards remain the same. We have further documentation that this is still a problem in evacuations. For example, people still try to drive vehicles through floodwaters even when warned that the waters are dangerous. During the Cheyenne flood in Wyoming, most of the deaths were caused by persons driving their cars into flooded streams and being swept away in the floodwaters (Sorensen 1987). Furthermore, warning the public that high levels of radon can contribute to respiratory problems has not led to public discussion or federal action regarding the hazard (Smith et al. 1988). Dudley and Lee (1988) found that during a 1986 tsunami alert in Honolulu, Hawaii, people refused to evacuate from beach areas, the worst possible place to be during a tsunami.

2.3.3 Factors Affecting Ability to Evacuate

Two major issues have been raised concerning an individual's ability to evacuate. These issues include economic resources—can a person afford to relocate—and the problems associated with the physical withdrawal of special groups. These specialized groups include the institutionalized and individuals with physical or mental impairments in the general population.

2.3.3.1 Economic Resources

We better understand that when constraints are lifted people will be more likely to evacuate. Having shelters available is one way to facilitate low-income persons' evacuating. Bolin's (1986) work on use of shelters during the 1986 California floods indicates that transients or "non-routine victims" used shelters until shelters were closed. He also found that income was related to evacuation decision making.

2.3.3.2 Special or Institutionalized Populations

We have much more empirical evidence on needs of special populations in evacuating, but needs are not always met. In one study, bedridden residents waited several hours to be evacuated after the general public relocated following an explosion at a chemical plant in Taft, Louisiana (Environsphere 1983). Hargest (1982) has also questioned the adequacy of most hospital plans for the evacuation of patients away from the facility. Hargest (1982) notes that most chronic care facilities assume that fires within the facility will be quickly contained without need for evacuation of all patients. Some experimental research has indicated that mentally impaired individuals are capable of learning emergency procedures to protect themselves (Haney and Jones 1982). Most research in trade journals and in experimental work with physically impaired individuals suggests that specialized methods of notification are needed for disabled or mentally impaired individuals to cope successfully in emergency situations (Jones, Kazdin, and Haney 1981).

Probably one of the greatest problems in evacuating persons with special needs is determining where those people are among the general public. Most institutionalized populations, or those housed in special facilities, are known to local emergency planners or responders, but those persons scattered throughout the community may be inadvertently overlooked in an evacuation because of lack of identification.

Some disagreement exists on the identification of the disabled and their locations within the community (Levin 1980). The first disagreement concerns equity. Fire department personnel are required to rescue everybody on an equal basis. Some argue that knowing the location of a disabled person or group with special requirements may divert manpower to that location and away from an area of greater need. Others argue that mandatory registration of disabled or impaired individuals with the fire department may not result in increased effectiveness of evacuation or rescue. Furthermore, as a greater number of persons with impairments participate in activities in areas formerly inaccessible to them, there is the question of invasion of privacy, as many individuals do not wish to be singled out for special consideration.

Those arguing for identification insist that preplanning and knowing where special populations are located ease the job of emergency personnel and ensure that one less surprise will be encountered during an evacuation. Proponents for registration insist that impaired individuals need to let emergency responders know what special care or additional help they would need in an emergency. Conversely, emergency responders could then instruct such individuals and groups in safety measures that

would enhance their chances of survival in an emergency or during an evacuation. Preplanning requires cooperation and involvement of both responders and potential victims for maximum effectiveness during an emergency (Levin 1980).

Another problem is coordination of resources between emergency responders and managers of specialized populations. Because many of the needs are particular to the special population (for example, special diet foods or vehicles with loading platforms for wheelchairs), emergency planners are unaware of the requirements until the event and thus do not include them in emergency response budgets. Even agencies such as the Red Cross do not routinely provide adequate food, bedding, or medical attention during emergency evacuations of the elderly or the physically or mentally impaired. Such issues as providing emergency shelter in buildings with upper floors for people dependent on wheelchairs or walkers have caused concern about the shelter needs of special populations. Few communities other than Pinellas County, Florida, have integrated evacuation plans that consider the plight of special populations, let alone their special requirements (Vogt 1990).

2.4 ORGANIZATIONAL ISSUES

2.4.1 Planning Elements Are Inadequate

A major concern for critics of evacuation planning is that the elements used as a basis for planning strategies are inadequate. Critics argue that:

1. coordination of planning is lacking,
2. planning for shelters is inadequate,
3. plans are lacking,
4. planning for secondary hazards is needed,
5. a definition of the EPZ is needed,
6. plans for institutional facilities and special populations are needed,
7. planning for re-entry is needed,
8. there is no support for planning,
9. planning is needed for emergency resources to support evacuation,
10. planning is needed for medical and health care of evacuees,
11. planning is needed for extended evacuations, and
12. planning uses wrong assumptions.

2.4.1.1 Coordination of Planning Is Lacking

Research suggests that inter- and intra-organizational coordination among agencies is improving. We know lack of intergovernmental cooperation affects evacuations effectiveness by delaying response and in timeliness of providing assistance (Hushon, Kelly, and Rubin 1989). Discussion of the Sumter County, Alabama, integrated plan for emergencies by Faupel et al. (1987) is one example of interagency coordination. FEMA's (1989) two-part manual on emergency planning and preparedness questions the physical-capacity and staffing requirements for evacuation shelters. Graham's (1985) hurricane evacuation studies demonstrate the effectiveness of coordination resulting from joint efforts of the U.S. Army Corps of Engineers, FEMA, and National Oceanic and Atmospheric Administration in development of the SLOSH models for determining areas to be evacuated from a storm surge.

Probably one of the most useful guides on integrated planning for hazardous materials emergencies for small communities comes from the Kansas State University study (Garten and Russel 1985). The guide analyzes efforts of 11 communities using a risk-vulnerability model and offers recommendations that mitigate the effects of hazardous materials accidents in rural areas.

2.4.1.2 Inadequate Planning for Shelters

We have additional research on how to improve plans for shelters, although knowledge is not always incorporated in evacuation plans. We also have a better understanding of who uses public shelters and the different factors affecting evacuee shelter use for temporary or extended evacuations. Figure 2, drawn from a multiple of sources, shows the levels of use of official shelters for a number of events.

There is also new evidence that shelter use is a more complex issue than previously thought by researchers. Factors influencing shelter use are:

1. socioeconomic status (SES) and age (which covaries with SES),
2. type of hazard,
3. length of time of evacuation,
4. location of hazard (urban vs rural),
5. degree of threat (how far the hazard area extends), and
6. whether registration is necessary for financial compensation.

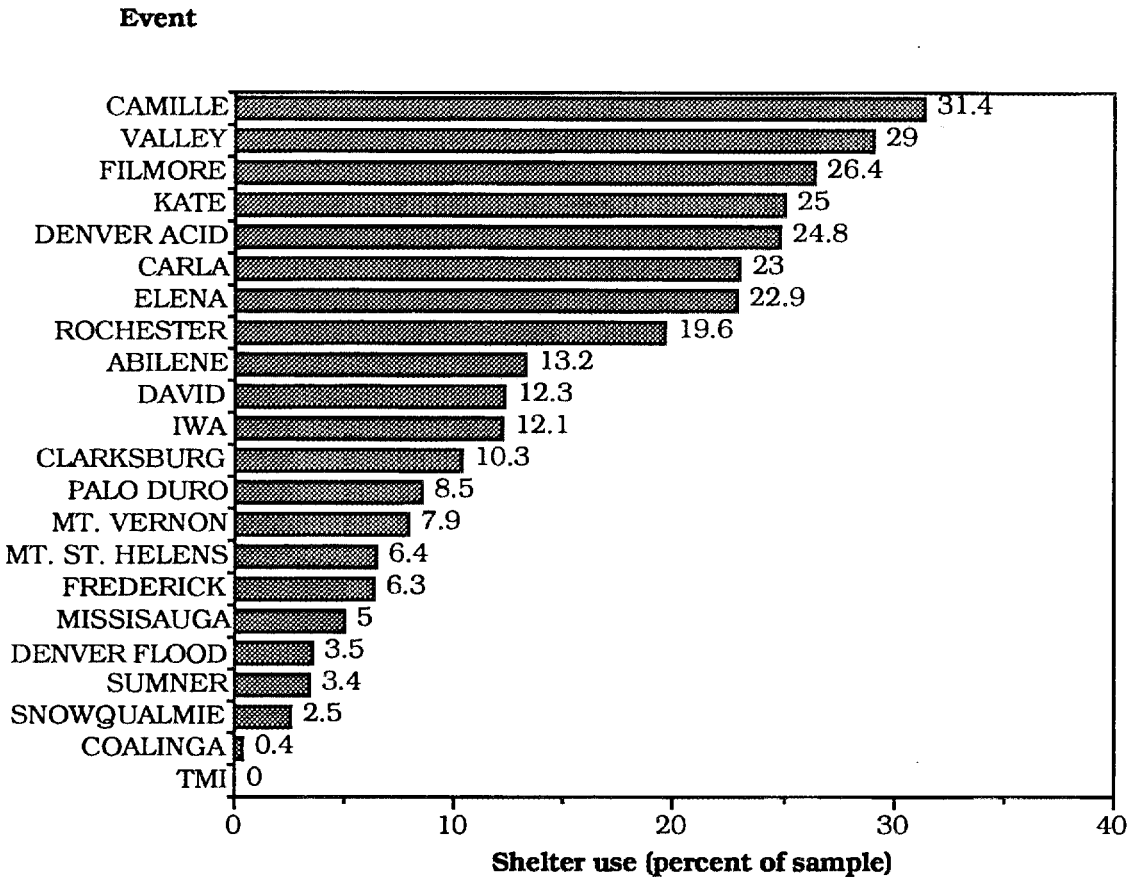


Fig. 2. Shelter use estimates from behavioral surveys.

Bolin's (1986) empirical study on extended use of shelters during floods in California found transients among evacuees using shelters. Anecdotal evidence from the Loma Prieta earthquake suggests that unauthorized persons sought financial aid by filling out the necessary registration forms at some shelters. Nelson et al. (1988) surveyed evacuees as well as workers at shelters during a 1985 Florida hurricane and found health care in shelters woefully inadequate. In one case, a single nurse was assigned to a shelter housing approximately 3,000 evacuees. The study also found that shelters were not always opened in a timely manner in areas where evacuation of populations is known to occur (Nelson et al. 1988). Many of the nurses who volunteered to work in the shelters worked from 24 to 36 hours without relief (Brown et al. 1988). The Duclos, Binder, and Reister (1989) report of the Nanticoke evacuation listed numerous recommendations made by evacuees to render shelters more habitable. The suggestions included increasing the number of shelters, providing more basic

equipment such as chairs and bathrooms, and giving more consideration to elderly evacuees, such as providing medical services within shelters.

The study of evacuees registered in emergency shelters during Hurricane Elena by Brown et al. (1988) found that, although 83% of respondents rated the shelter experience as positive, evacuees complained of crowded conditions, uncontrolled people, excessive noise, lack of restroom facilities and general supplies, unsanitary conditions, and poor quality of food. One-fourth of the respondents believed that the numbers of shelters and the size of some shelters were not adequate and contributed toward the crowded conditions. The largest cohort evacuated were persons more than 65 years of age; 40% of these people identified at least one health problem. In addition, Brown et al. found that:

- 25% of shelter evacuees believed there were not enough nurses assigned to shelters;
- 94% of evacuees in shelters had never previously evacuated, and 54% had never experienced a hurricane;
- 34% were notified to evacuate by friends, 32% by police, and 22% by media;
- fewer than half of the respondents went to shelters to which they were assigned;
- 60% of respondents felt prepared for the storm before being asked to evacuate, and 70% felt they had adequate notice before evacuating;
- 82% travelled to the shelter in their cars; and
- 75% of respondents expected to be away from their homes for 24 hours or less.

Other researchers have criticized how shelters are designated and managed. Babineau (1989) criticizes emergency planners for designating as shelters buildings never intended to house large numbers of people for periods of time. Babineau advocates instituting fire safety procedures within shelters that are known to all evacuees and that take into account the possibility of power failures. Others note that, in addition to the need for adequate shelters, the coordination of shelter management needs considerable improvement (Environsphere 1983; Nelson et al. 1988; Nelson et al. 1989).

The criticisms have not gone unnoticed. The Florida Department of Health and Rehabilitative Services has designated public health nurses to function as shelter nurses in future evacuations. Other Florida interagency agreements have also resulted in plans for three special care shelters for evacuees with significant health problems (including nursing home clients) that will have more services and medical personnel available (Brown et al. 1988).

2.4.1.3 Lack of Plans

We have more information on the level of planning, particularly since community plans for emergencies were mandated for hazardous materials threats under SARA Title III. It may be that Canada has more integration in planning among local, provincial, and federal agencies than similar political entities in the United States that still battle over jurisdictional boundaries when addressing problems in emergency management.

Faupel et al. (1987) examined emergency planning for hazardous waste and other emergencies in Sumter County, Alabama, through semi-structured interviews of organizational officials. The study focused on the extent of public involvement in decision-making processes regarding hazardous waste management in Alabama and the impact of the waste industry on local community planning for emergencies. While individual organizations had emergency plans, the near absence of overall formal planning with a distinct reliance on the waste management industry for response efforts indicated a lack of integration among agencies, especially in knowledge of the vertical relationships and extra-community resources that could significantly affect immediate emergency response and inhibit planning for mitigation and recovery.

Nehnevajsa's (1990) report on emergency preparedness found 78.6% of the 2,345 local and county emergency management officials (EMOs) surveyed had plans in place to issue timely evacuation information; 72.8% had plans to secure an evacuated area. Of those that had experienced evacuations, only 22.8% considered their plans very effective, 2.3% considered their plans ineffective, and 57.5% claimed their plans were somewhat effective, but not very effective, indicating improvements were in order.

2.4.1.4 Planning for Secondary Hazards

Planning for secondary hazards is still a problem but is being better addressed for certain threats such as hurricanes and seismic disturbances. Hurricane advisories now discuss tornadoes as possible secondary hazards. Earthquake information frequently mentions preparing for aftershocks, mudslides, and the possibility of power failure or other loss of services.

2.4.1.5 Definition of Emergency Planning Zones

Additional work and alternatives on concerns relating to EPZ delineation have expanded the initially narrow EPZ definition. Since Chernobyl, alternatives to designating specific geographical areas as EPZs have surfaced. Golding and Kasperson (1988) pointed out that regional, rather than local, strategies for dealing with plume dispersals of radionuclides may be most effective for planning for radiological accidents. Evacuation plans would have contingencies for accommodating extensive releases. What has changed is the move for emergency planners to acknowledge the worst case scenario as a possibility for nuclear accidents.

In the *Title III Technical Guidance for Hazard Analysis: Emergency Planning for Extremely Hazardous Substances* (EPA/FEMA/DOT 1987), a single-zone concept is recommended for each chemical stored at a facility. The zone is based on a vulnerability estimate that is based on estimates of downwind dispersion of chemicals. Distance is determined by estimating a level of concern, defined as the concentration of a chemical in the air, above which there may be serious irreversible health effects.

For the Chemical Stockpile Disposal Program, three planning zones were developed to provide more flexibility than offered by the REP or SARA program. EPZs, developed in consideration of the risk analysis, available response time, distance, and protective action options, establish the areas where the emergency response concepts are applied. The EPZ concept and its three zones reflect the differing emergency response requirements associated with the potential rapid onset of an accidental release of agent and the amount of time that may be available for warning and response. They were developed in recognition of the importance of comprehensive emergency response planning and support systems for rapidly occurring events and the critical nature of such programs in areas nearest the release point. The EPZs were intended to guide the development of emergency response concepts and were not intended to be applied mechanistically or inflexibly to specific sites, alternatives, or a specific accident scenario. Development of actual EPZs takes into account unique political, social, geographical, and stockpile characteristics of each site. Conceptually, criteria for establishing the EPZs are applied consistently across the program; however, specific configurations and associated distances may vary from site to site. The EPZs are partitioned into three specific subzones: the innermost zone is an immediate response zone, the middle zone is the protective action zone, and the outermost zone is the precautionary zone. The subzones are based on the types of accidents identified for all of the sites and the amount of time available to pursue appropriate protection actions.

2.4.1.6 Plans for Institutional Facilities and Special Populations

Nehnevajsa's (1990) report on emergency preparedness found that 63.6% of the 2,345 EMOs surveyed had plans to evacuate special populations, but only 36.8% had plans to evacuate persons with special needs within the general population. At least half (54.4%) of the communities did not have any plans for identifying such people within the general population.

Following Archea's (1979) earlier work, considerable research has begun on emergency planning for institutional facilities and facilities housing special populations (Aghababian 1986; Auf der Heide 1989). Attention to planning may have to do with liability issues as well as greater awareness of the special requirements of such populations. Some researchers argue that the integration of persons with physical impairments into the general population and the expansion of laws against discrimination in the work place have forced emergency planners to reconsider emergency measures. Other research, mainly elaborated in trade journals, discusses how emergency responders can prepare for the evacuation of resistive persons during emergencies (Klein 1987). Emergency planners, architects, and emergency responders now recognize the need for places of refuge where the physically impaired can seek shelter during an evacuation until they can be removed from the facility. Some facilities have elevators designated for incapacitated persons during fires or other emergencies. Many buildings, however, still prohibit the use of elevators during emergencies—a fact that must anger wheelchair-bound persons.

The myth of increased morbidity or mortality from moving hospital or nursing home patients is gradually being erased from emergency planning of health facilities. Even though some hospital patients were forced to move more than once during the Mississauga evacuation, neither the hospital staff nor the administration found any deaths or increase in morbidity attributable to the evacuation experience (Henry 1980).

2.4.1.7 Planning for Re-entry

Planning for re-entry remains an issue often not addressed in plans. What is known on re-entry procedures is not always implemented. We know residents want to return as soon as possible to evacuated homes, that they don't travel far from home, and that considerable antagonism results if they are forced to remain away from their homes. Research from Hurricane Elena evacuees indicated that approximately 75% of evacuees sought refuge in their home counties (Nelson et al. 1988). Re-entry to

designated evacuated areas was a significant issue in Hurricane Elena (Nelson et al. 1988).

Guidelines for re-entry into an area following a chemical release are practically nonexistent, as are protocols and equipment for environmental monitoring in evacuated areas. In a train derailment at Miamisburg, Ohio, where white phosphorous ignited, citizens returned to their homes after being evacuated, only to be forced to evacuate again as the situation worsened (Menker and Floren 1986).

2.4.1.8 No Support for Planning

Lack of support for planning is an ongoing issue, although great progress has been made to generate increased interest in planning. Federal regulations require planning for hazardous chemical accidents through the implementation of Local Emergency Planning Committees (LEPCs); SARA Title III has generated much of this support (Harper 1989).

2.4.1.9 Planning for Emergency Resources to Support Evacuation

Some researchers have suggested that emergency planning should be comprehensive in coverage and should include planning for mitigation and recovery (Faupel et al. 1987), a further extension of emergency resources.

2.4.1.10 Planning for Medical and Health Care of Evacuees

New data are available that have provided better information on medical needs of evacuees in shelters. Evidence suggests that shelters have been understaffed in terms of medical care (Brown et al. 1988), and neither safety nor security of evacuees is a high priority in shelters (Bolin 1986). New evidence, primarily from medical staff at shelters, indicates that higher levels of medical and health care are needed, especially in areas where the major cohort of evacuees is aged, infirm, or otherwise incapacitated (Brown et al. 1988).

2.4.1.11 Planning for Extended Evacuations

No new evidence has been found on extended evacuations other than that provided by Bolin's (1986) study of evacuees in the California floods. Bolin (1986) found that extended evacuations increased hardships for lower-income evacuees. Anecdotal material from the Chernobyl accident suggests that planning for an extended evacuation of an area will have to be at the federal level, encompassing planning not presently addressed. The research on Hurricane Elena indicated that a stall of weather delaying evacuees' return to their homes results in unplanned burdens on shelter staff and resources (Brown et al. 1988; Nelson et al. 1988).

2.4.1.12 Planning Uses Wrong Assumptions

Evidence suggests a shift is occurring in the assumptions planners use in deciding to evacuate. Harrison and Bellamy's (1988) work on models for toxic releases increases the capacity of emergency planners to analyze factors that make evacuation a worthwhile option. Whether planners should use worst case scenario assumptions in developing plans is now an issue (Golding and Kasperson 1988). After the Exxon Valdez oil spill, government officials were criticized for not being prepared for worst case events.

2.4.2 The Technical Basis for Evacuation Planning Is Inadequate

Criticism has also been levied at the technologies used as a basis for planning evacuation strategies. Among these criticisms are that:

1. evacuation time estimates are inaccurate,
2. plans will lead to unnecessary evacuations,
3. organizations for developing plans are lacking,
4. organizations with responsibilities downplay the hazard,
5. knowledge is not transferable,
6. dissemination of technical knowledge is poor, and
7. populations at risk are unknown.

2.4.2.1 Evacuation Time Estimates Are Inaccurate

Several changes have occurred in transportation models used to estimate evacuation times. Researchers can now provide better assumptions for such models by including behavioral factors. Research also indicates that better models are needed and that most models remain without empirical validation. Work by Southworth and Chin (1987) has provided real-time estimates on the number of vehicles crossing an egress point, but assumptions on numbers of vehicles rely on estimates of 1.3 persons per vehicle—a factor that remains unconfirmed. Another criticism of transportation models concerns the sampling frame for collecting evacuation information. Critics claim that surveying only residents evacuated from threatened areas does not account for voluntary evacuation by residents from nonvulnerable areas (Nelson et al. 1988).

There has been a shift to interactive models and away from cookbook types of procedural guidelines. Personal computers have made planning models more accessible to emergency planners, both for simulating emergency situations in planning and in determining factors that should be considered in actual events, especially in chemical or hazardous spill situations.

2.4.2.2 Plans Will Lead to Unnecessary Evacuations

The concept that having evacuation plans will lead to unnecessary evacuations is not an issue. With local emergency planning mandated by federal agencies, having evacuation plans is now standard procedure—even if they are nothing more than "paper." On the contrary, many emergency planners are becoming aware that getting people to believe that they are threatened and should evacuate is a more acute problem.

2.4.2.3 Organizations for Developing Plans Are Lacking

The SARA Title III mandate for LEPCs has provided the impetus for developing plans for hazardous materials at fixed sites. Organization for transportation accidents is more problematic. Using DOT guidelines to select routes for the transportation of spent nuclear fuel rods in Virginia, Hobeika et al. (1985) suggest several modifications to enhance the public's safety from an accidental spill and to maximize community preparedness in terms of response and evacuation capability. Binder's (1989) work on national data bases on chemical accidents showed there is no central mechanism for reporting accident experience and validating information on hazardous material releases

and evacuations. No mechanism for tracking the implementation of Title III planning exists. Such problems help illustrate that a stronger federal organization is needed to facilitate planning.

2.4.2.4 Organizations With Responsibilities Downplay the Hazard

Many communities and organizations have significantly changed their attitudes about planning for hazardous materials since SARA Title III went into effect (Kartez 1989). Also, the liability aspect from increased public exposure may have prompted corporate owners and operators of hazardous facilities to reduce risks.

2.4.2.5 Transfer of Knowledge

There is growing adoption of multi-hazard planning with hazard-specific variance described within the plans. Use of research derived from different hazard events is increasing. For example, an emergency physician developed a comprehensive handbook on disaster response by reviewing material outside the medical literature and relating that data to a hospital's response to disaster (Auf der Heide 1989). Other researchers have examined a variety of international disasters and hazardous events to determine the common threads that affect crisis management (Rosenthal et al. 1989). Comparisons between the accidents at Chernobyl and Three Mile Island (TMI) indicate that confusion hampered organizational response in both events (Lowenhardt and van den Berg 1989).

2.4.2.6 Dissemination of Technical Knowledge Is Poor

Dissemination of technical knowledge is improving, especially among emergency responders. The readiness of corporations and organizations, particularly in the chemical industries, to participate in emergencies with information and resources has greatly increased community responders' reservoir for factual response. Much of the information initially contained in guides and manuals is now easily transmitted through personal computers or other hardware available to local emergency agencies.

2.4.2.7 Populations at Risk Are Unknown

Knowledge about specific populations at risk is improving but is still not fully incorporated into emergency plans. For example, knowledge of numbers of evacuees is not always translated into shelter requirements (Nelson et al. 1988). Hillsman and Coleman (1989) describe a method for using census data to estimate population at risk around fixed sites and along transportation corridors.

Problems exist with estimating subgroups at risk. People with special needs scattered within a community remain unknown to emergency planners and generally are not included in plans for specialized warning signals or devices. In addition, no reliable means exists for estimating populations at work or the distribution of people during daytime hours. The Tiger File structure of the 1990 Census, in which population will be assigned to streets, will greatly facilitate identifying the location of people for emergency planning.

2.5 RESPONSE ISSUES

2.5.1 Physical Factors Constrain Evacuation

The following are significant physical factors constraining evacuation:

1. Population is too dense to evacuate.
2. Population in areas with seasonal peaks is difficult.
3. Boats will interfere with island evacuation.
4. Traffic accidents will constrain evacuation.

2.5.1.1 Population Is Too Dense to Evacuate

Research has produced evidence that evacuation time is not correlated with size of population. During Hurricane Gloria, six million people evacuated. An alert for a tsunami in 1986 reportedly resulted in hopelessly crowded streets in downtown Honolulu, Hawaii, as businesses closed early to let people go home (Dudley and Lee 1988). Bellamy's (1986) review of evacuation data found no relationship between population and evacuation rates. Pauls' (1984) work with movement of people evacuating under emergency conditions found that a number of factors other than size influence movement of crowds out of buildings. Such factors include height of stair risers, width of stairwells, evacuee familiarity with egress routes, and types of clothing

worn by evacuees. Pauls' research indicates that adjustments to design of public spaces could significantly affect evacuation rates, especially where large crowds frequently congregate.

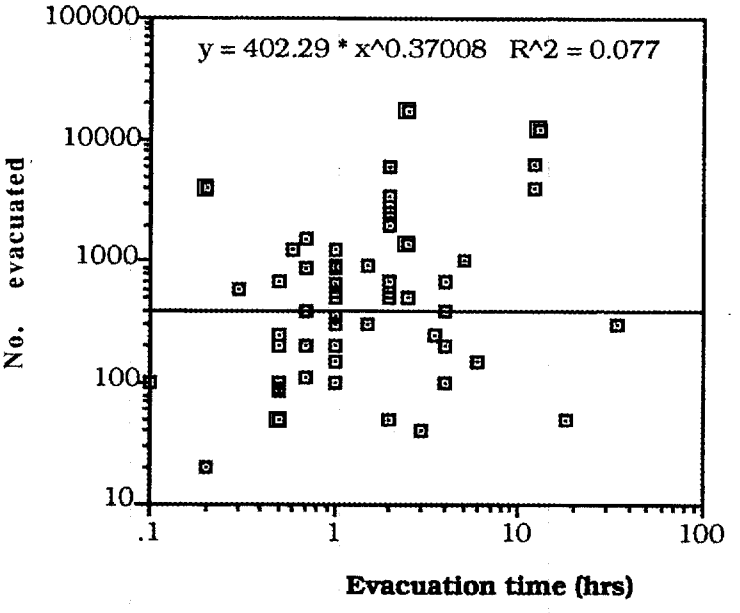
A study was conducted at Pennsylvania State University on evacuation risks (Witzig and Shillenn 1987). Data were collected from surveys of about 310 evacuations in the United States that were sent to local emergency managers. While the purpose of the study was to estimate the risks of injury and fatality in an evacuation, the data collected can be used to address other interesting emergency planning questions. Figure 3 shows data on the estimated size of the evacuation (as measured by the number of evacuees) and the estimated clearance times (as measured by the time it took to complete the evacuation to a safe location). This enables us to determine whether it takes longer to move a greater number of people. The results, which are based on all chemical accidents with warning times of less than 10 hours, indicate that there is no significant relationship between the two variables. Prevailing logic among emergency planners is that it takes more time to move a greater number of people; this is not true.

We suspect that two factors intervene. First, the time it takes to evacuate is partly determined by the urgency of the situation. If there is the need to move quickly, people respond accordingly. If the situation is not immediately threatening, people take more time. Second, as population increases, the infrastructure needed to move a greater number of people also increases. To test this latter proposition, we compared the size of the evacuation with the evacuation rate as measured by the number evacuating per hour (Fig. 3). Here we see a strong, significant relationship. As the number evacuating increases, the rate also increases. This supports the notion that proper infrastructures help move larger populations in time frames similar to those associated with smaller populations.

2.5.1.2 Evacuation in Areas with Seasonal Peaks Is Difficult

Some additional research has been conducted in areas with a large number of tourists. During a 1986 tsunami alert in tourist-oriented Honolulu, Dudley and Lee (1988) found that people (including many visitors) when warned of the threat refused to leave the beaches—evacuation being the only sure form of protection from tsunami inundation. Dudley and Lee (1988) suggest that stronger enforcement by government agencies is the only method to secure evacuation of threatened populations in such areas.

Evacuation time by size for chemical spills and fires



Evacuation rate by size for chemical spills and fires

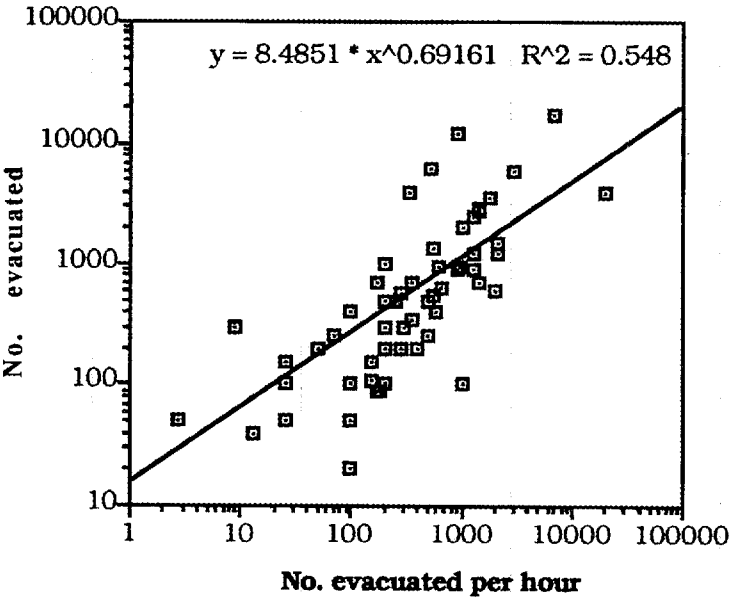


Fig. 3. Evacuation time and rate by population size.

2.5.1.3 Boats Will Interfere with Island Evacuation

Presently most plans do not advocate leaving drawbridges up when people are evacuating.

2.5.1.4 Traffic Accidents Will Constrain Evacuation

Evidence continues to show that accidents are not a problem in evacuations. Data from Bastien et al. (1985) that analyze traffic accidents during evacuations found no driving accidents for the 1.5 million people who evacuated during various events. The direct use of statistical results of average road conditions produced an overestimation (and unsupported estimation) of deaths and injuries during evacuations (Bastien et al. 1985). Witzig and Shillenn (1987) conducted a study of accidents in more than 300 evacuations; they were able to document 12 injuries but no deaths attributable to accidents during evacuations. Traffic jams were more likely during re-entry rather than egress. Sorensen (1986, 1987) examined nearly 300 evacuations caused by chemical accidents from 1980 to 1984 and found no evidence of injuries or fatalities from traffic accidents.

2.5.2 Public Behavior

Arguments that the public will not cooperate or respond appropriately with authorities are based on the following challenges:

1. People will hold parties instead.
2. Problems with "evacuation shadow" will occur.
3. People will panic.
4. Convergence will occur, hindering evacuation management.
5. Spontaneous evacuation will hinder evacuation management.
6. Aberrant behavior will occur.
7. People will not use designated routes.
8. Stress will occur during evacuation.
9. People will not obey officials.
10. People will not evacuate for long periods of time.
11. People do not know how to evacuate.
12. People will shelter instead of evacuating.

13. People will not go to designated host areas.
14. In extreme events, total social chaos would occur.

2.5.2.1 People Will Hold Parties

We have not found any research to document anecdotal reports that people behave inappropriately during times of real threat. However, Dudley and Lee (1988) reported that bars remained open for business during a tsunami alert in Hawaii in 1986. That people usually behave appropriately during emergencies when they believe they are at risk remains a valid assumption.

People's converging into groups during emergencies may be what is confused with "partying." The convergence phenomenon was first observed in a study of occupant behavior in a high-rise building fire in 1979 and later documented from reports by survivors of the MGM Grand Hotel fire in Las Vegas in 1980 (Bryan 1982). When guests were restricted from evacuating the building, many chose to converge in specific rooms selected as areas of refuge rather than returning to their own quarters. Guests tended to select rooms on specific sides of the building, often with balconies or doors leading to balconies because of ventilation, reduced smoke, improved visibility, and communication opportunities offered by balconies (Bryan 1982). The cluster was usually maintained in the room until help arrived or the occupants were notified by fire or rescue personnel that evacuation was possible. The smallest number of people identified as a cluster involved three persons; the largest, 35. The action of "offering refuge in room," identified among the fifth group of most common actions taken by respondents after becoming aware of the fire, suggests the convergence was intentional (Bryan 1982).

2.5.2.2 Evacuation Shadow

Evacuation shadow refers to people leaving areas next to officially evacuated areas. Some researchers (Sorensen 1986b; Mileti and Sorensen 1988) have challenged the assumptions of the alleged shadow phenomenon (i.e., evacuation overresponse) to the TMI accident. Sorensen's (1986b) work from the TMI behavioral studies completed after the accidental radiological release indicates that the so-called "evacuation shadow" exists primarily within researchers' assumptions about who should and should not have evacuated. Supported by empirical evidence from behavioral studies of TMI, the findings suggest people acted normally, given the ambiguity of the situation. Evidence

suggests evacuation was a prudent response that did not need to follow from an official order. The myth of public overresponse to radiological releases may lead emergency planners to forget that some members of the public refuse to heed a warning, a decision that could be fatal in a radiological accident.

Additional insight into this question is provided by other behavioral surveys where evacuation zones are defined. Nelson, Kurtz, and Hacker (1988) surveyed 2,820 residents living in four counties within the Tampa Bay area about their evacuation experiences during Hurricane Elena. Residents both within and outside evacuation areas were contacted to find out who evacuated, why they left, where they went to shelter, and how long it took them to leave their homes. Thirty-two percent of respondents who should have evacuated during Hurricane Elena did not evacuate, while 22% of those who lived in areas adjacent to areas ordered evacuated also left their home. Respondents who did not evacuate felt that the storm was not severe enough or that their homes were safe shelters (33%) because they lived on high ground (23%); 8% who should have evacuated cited "did not feel like it" as a reason for nonevacuation. The highest evacuation rates were on the barrier islands, where 90% of residents left their residences.

Johnson and Ziegler's (1989) conclusions on evacuation overresponse have largely been derived from behavioral intent studies that have not received empirical validation. Studies on Hurricane Elena by Nelson et al. (1988) indicate behavioral intent studies do not predict actual behavior in emergencies. They were able to compare people's behavioral intents to evacuate to different destinations collected in the hurricane planning surveys to actual behavior during Elena. Behavioral intent data greatly overestimated the number of people who would evacuate to official shelters.

2.5.2.3 Panic

Research on egress during fires suggests that panic among evacuees rarely occurs. Data from the MGM fire suggest that, even when dangerous conditions do occur, panic doesn't necessarily ensue (Bryan 1982). The problem is that journalists continue to confuse stress arousal with panic behavior. Bellamy's (1986) review of evacuation data found that people acted appropriately in most emergencies involving fires and responded without prior knowledge of what to do except when situations appeared hopeless.

2.5.2.4 Convergence

Probably one of the most interesting findings on convergence comes from fire literature. One study found people who unsuccessfully attempted to evacuate during the MGM hotel fire had converged in clusters of 3 to 35 persons in specific rooms used as refuges (Bryan 1982). Emergency planners in Japan have extended the convergence concept to enhance evacuation effectiveness from fires by encouraging the formation of groups with previously designated leaders to direct employee evacuations.

Also noted in the literature is the convergence of volunteers, helpers, and on-lookers to impacted areas, whatever the threat or event. Reducing media convergence is becoming an issue, especially if terrorism (Scanlon 1990) or medical response efforts (Auf der Heide 1989) are involved and emergency response efforts are hampered.

2.5.2.5 Spontaneous Evacuation

Research shows that many people leave before being directed or ordered to—particularly if direct confirmation of a threat is received before an official warning is made. After a chemical plant explosion on the Mississippi River, people left immediately after hearing the blast, returned to their homes, and then left again when ordered to do so by officials (Environsphere 1983). Evidence from reports by people who evacuated during Hurricane Elena indicates that 22% of people who lived in areas adjacent to areas ordered evacuated also left their homes and sought refuge at public shelters (Nelson et al. 1988).

2.5.2.6 Aberrant Behavior

Most of the aberrant behavior discussed in evacuations concerns looting. We now find that looting occurs in areas with distinct class differences, where the opportunity presents itself to the disadvantaged persons. Generally, looting occurs within third world countries when there is competition for scarce resources. In some of the largest evacuations to date in the United States, looting has not been a problem. A review by Schneider Environmental Planning and Management Services (1987) of the Nanticoke, Pennsylvania, evacuation of 14,050 residents found no evidence of injuries, panic, looting, or traffic accidents in any report made by an organization involved in the event. Bellamy (1986), synthesizing available evacuation data from toxic cloud

incidents, found most people acted appropriately and responded to direct warnings from officials, although some motorists confused toxic vapor clouds with fog.

2.5.2.7 People Will Not Use Designated Routes

Behavioral studies indicate that people evacuating a building will use the most familiar routes to them, rather than unfamiliar designated emergency exits, unless those familiar routes are blocked (Horiuchi, Murozaki, and Hokugo 1986).

2.5.2.8 Stress Will Occur During Evacuation

We have additional evidence that permanent or extended relocation stresses individuals involved. Some level of stress is found among evacuees after a disaster but does not indicate a permanent problem. Bolin's work (1986) found lower-income evacuees suffered more stress than higher-income victims, probably because lower-income respondents had less extensive support networks to ease evacuation-induced traumas. Much of the reported stress occurs among emergency responders, especially when identification of bodies or body parts is part of the workload, and among those assigned tasks for long durations (National Institute of Mental Health 1986).

2.5.2.9 People Will Not Obey Officials

More work has been done on compliance with warning recommendations. Compliance with evacuation recommendations appears to be affected by minority status (Perry and Mushkatel 1986). Perry (1987) also suggests from his research that some minority group members perceive authority figures—particularly uniformed "government" representatives—differently than do majority group members. Perry (1987) also offers evidence that no ethnic differentials exist with regard to the relationships between warning belief and personal risk and warning compliance. Higher levels of warning belief and personal risk are correlated with higher levels of warning compliance. The higher the credibility of the warning source, the more likely the development of high levels of warning belief and assessment of personal risk; consequently, it is more likely the recipient will engage in a protective action. The accomplishment of emergency management tasks depends on knowing the degree of ethnic composition of any given community.

Nelson et al. (1988), studying evacuation compliance during hurricane threats in Florida, found that 68% of the residents in the mandatory evacuation zones actually left, and 75% of the mobile-home owners—those most adversely affected given a severe storm threat—left when told to evacuate. Of the 32% of people who did not evacuate as directed during Hurricane Elena, 33% said they considered their homes to be a safe shelter, 23% said the storm was not severe enough to warrant evacuation, and 8% said they "did not feel like it" (Nelson, Kurtz, and Hacker 1988).

2.5.2.10 People Will Not Evacuate for Long Periods of Time

Further support from hurricane studies by Nelson et al. (1988) indicates that people want to return home as soon as possible. (See Sect. 2.4.1.7 for further information.)

2.5.2.11 People Do Not Know How To Evacuate

Findings from the Hurricane Elena shelter study (Nelson et al. 1988) indicate that the majority of respondents did not know what provisions the shelter would afford. Those who did indicate knowledge of shelter provisions learned this information from a newspaper tabloid (31.2% of 314 respondents). In the Cheyenne, Wyoming, flash flood, people did not understand the problems of evacuating across a flooded stream (Sorensen 1987).

2.5.2.12 People Will Shelter Instead of Evacuating

We only have speculation or unsupported anecdotal observations about whether people will evacuate when advised to shelter. Bloomquist et. al (1986) suggest that in certain circumstances (such as during radioactive releases in Finland) sheltering may offer greater protection than would evacuation but that public opinion did not support the concept. Bellamy's (1986) research also indicates that in chlorine clouds of high concentrations, buildings are safer places of refuge than cars, which generally offer some protection for about 15 minutes before stalling in the heavy vapors of chlorine or ammonia.

2.5.2.13 People Will Not Go to Designated Host Areas

Information on where people go in evacuations is improving but is not changing earlier findings that most people choose to stay with family or friends during an evacuation (Nelson, Kurtz, and Hacker 1988). Information on shelters indicates SES affects shelter choices. It is speculated that people from lower-income groups have lower resources and less-extensive social networks and must rely more on public assistance during evacuations (Bolin 1986).

2.5.2.14 Total Social Chaos

Whether nuclear war would destroy a society and cause total social chaos is not an issue in the light of international political developments. The Chernobyl radiological accident, which resulted in total relocation of 135,000 people, did not result in chaos either during or following the relocation (Orchard 1988).

2.5.3 Emergency Worker Behavior

2.5.3.1 Role Abandonment

We have further evidence that role conflict during emergencies is not a problem, especially when work roles are of helper or emergency type. Evidence from the studies of health care facilities (Vogt 1990) indicates that emergency workers frequently enlist the aid of families and friends to expedite evacuations. Moreover, emergency workers generally attend to their work roles for much longer periods than during normal operations, prompting many manuals to suggest that disaster plans include instructions for a change of command and require periods of rest for emergency responders.

2.5.4 Evacuation Is Not Perceived as Public Good

Three issues are related to the concern about the value of evacuation planning:

1. evacuation puts people at greater risk;
2. people have a right to stay; and
3. evacuation planning creates liabilities.

2.5.4.1 Evacuation Puts People at Greater Risk

Knowledge is improving about when evacuation places people at risk (Koch and Tadmore 1988). Decision making about evacuating vs sheltering—particularly in fast-moving hazardous-materials and chemical releases—remains a problem for public officials. Glickman and Ujihara (1990) examined the benefits of in-place protective actions vs evacuation in the event of a toxic vapor cloud emergency. In-place protection may be preferable if fast-moving vapor clouds are present, because buildings provide a reservoir of clean air; however, if infiltration is a problem, staying indoors may not be adequate without additional measures.

Evacuation is preferable when the release has not occurred or when the release threatens to create a fireball or explosion. In-place protection takes much less time to accomplish than an evacuation, especially when the public has been educated to recognize warning signals. Glickman and Ujihara (1990) propose a matrix for determining the most appropriate protective action (sheltering vs evacuation) based on calculations of the estimated values of maximum indoor dose and the estimated time of arrival of the toxic cloud for each quadrant. Unlike most areas of the United States, standard operating procedures in Europe tend to emphasize in-place protection in response to chemical-release emergencies.

The Nuclear Regulatory Commission's position on protective actions for an emergency at a nuclear power plant is that, in a declaration of a general emergency, immediate evacuation of impacted areas is recommended (Martin and McKenna 1988).

2.5.4.2 People Have a Right to Stay

Whether people have a right to remain in their homes is not an issue. Whether people evacuate is a choice they make for themselves in most states. There is no federal mandate that makes noncompliance for private individuals a cause for legal action against them. In certain situations, there are advantages for people sheltering rather than evacuating. Toxic clouds that move or spread rapidly may preclude some people from evacuating. In some situations, it is preferable for the physically impaired or disabled to go to places of refuge instead of evacuating with the general population. Unless the action places others at risk, remaining in-place during an emergency generally remains an individual choice.

2.5.4.3 Evacuation Planning Creates Liabilities

More work is being done on how evacuation planning increases liability for agencies and communities. At present there are no great insights on how penalties and right-to-know issues will affect planning for evacuations.

2.5.5 New Evacuation Issues

Several new issues have attracted researchers' and policy makers' attention. Among the concerns are:

1. the evacuation of companion animals and livestock,
2. municipal concerns for assessing and recovering losses from evacuations,
3. adequate documentation of hazards resulting in evacuations,
4. the use of expert systems in emergency planning,
5. that communities do not learn from experience with hazards,
6. the extent of the media's influence in evacuation response, and
7. the timing of evacuation response.

2.5.5.1 Evacuation of Companion Animals and Livestock

One issue not previously examined was what evacuees did with pets or other animals, such as livestock, when they left their homes. Evidence from the Hurricane Elena studies indicates that most evacuees either took their pets to a friend or relative or left them at home. A sample of 2,820 respondents, of whom 1,802 lived in hurricane evacuation zones, by Nelson et al. (1988) showed that only 765 respondents (less than half) evacuated. People who had pets at the time of the hurricane were less likely to evacuate. At least 25% of evacuees left their pets at home while they were gone. This knowledge is useful because public shelters do not allow pets to accompany evacuees. The 11.4% of evacuees who took their pets to shelters left the animals in vehicles for the duration of the stay. For a protracted evacuation or one in which toxic fumes were involved, leaving pets behind could be a significant problem: premature re-entry by evacuees could place residents at further risk. Cann (1990) found that during the 10-day Haggersfield evacuation from an area where burning tires created toxic fumes, residents routinely returned to their homes to care for livestock. Buck (1987) notes that, in certain situations, evacuating livestock may be the only measure offering

protection to animals. How that is best accomplished under various time frames remains problematic.

2.5.5.2 Assessing and Recovering Losses from Evacuations

As evacuations increase in number, so do the costs of planning, management, and cleanup. Assouline et al. (1987) suggest that economic losses from evacuations are dramatically affected by length of stay both for the local and regional economies and that evacuations in industrialized urban sectors create the greatest economic upheaval. Floren (1987) found that most costs recovered in the Miamisburg train derailment accident came from the railroad company. A law was later passed in the Ohio legislature determining that recovery of costs from hazardous materials accidents be assessed by municipalities involved in the response.

2.5.5.3 Documentation of Hazards Resulting in Evacuations

Questions have been raised about the reporting of hazards resulting in evacuations. Whether our information about the number of evacuations and the morbidity and mortality estimates are accurate is the underlying issue. Binder (1989) found incompleteness, inaccuracy, and significant bias after examining the three major national sources of data on reported deaths and injuries from acute chemical releases in the United States. Enforcing existing reporting laws and validating collected information could help reduce documentation problems (Binder 1989).

2.5.5.4 Use of Expert Systems in Emergency Planning

The use of expert systems and simulation models for evacuation planning has been questioned because many of the models have not been supported by empirical validation. Transportation modeling appears the most feasible for evacuation planning, with several validated models (Southworth and Chin 1987). People should question the reliance on generic expert systems to guide emergency response for unique events.

Among the computer models used for simulating emergency evacuations is one introduced by Banz and Newkirk (1987) that analyzes factors that lead to instituting an evacuation or advocating sheltering. Many computer models also allow for interactive feedback and for future integration of artificial intelligence procedures to help decision makers plan during actual emergencies. Berke and Stubbs' (1989) review of automated

decision support systems for microcomputers found such systems could enhance hurricane mitigation efforts.

2.5.5.5 Communities Do Not Learn From Experience with Hazards

A related issue in emergency planning is whether communities learn from experience and can incorporate lessons learned into preparing for future events. Arguments against the value of prior experience have to do with the reliability of organizational "memory" as personnel move in and out of positions and work roles. Analysis by Kartez and Lindell (1990) suggests that not incorporating lessons learned from an emergency into the official organizational structure of the community emergency plans means that mistakes will hamper future emergency responses. Their research suggests that incorporating lessons learned into written form facilitates later response. Kartez and Lindell (1990) also found that visible and active support by officials for emergency preparedness was a key factor in instituting planning for institutionalizing emergency response.

2.5.5.6 The Media's Influence in Evacuation Responses

There is no question that the print and broadcast media affect public understanding of the hazard and of the risks associated with the hazard. The issue is how to measure media's influence on public responses and how to use that leverage to enhance public knowledge and response to chronic hazards.

2.5.5.7 Timing of Evacuation Responses

Additional research has provided information on the timing of warning responses. Whereas few data existed on mobilization time (the time between the receipt of a warning and departure), researchers have compiled significant new information for a variety of emergency evacuations (Sorensen and Mileti 1989). Figure 4 illustrates the mobilization times observed for a series of events. The major conclusions from such research are that mobilization time decreases with the seriousness of the threat and that the cumulative distribution of times follows a logistic curve.

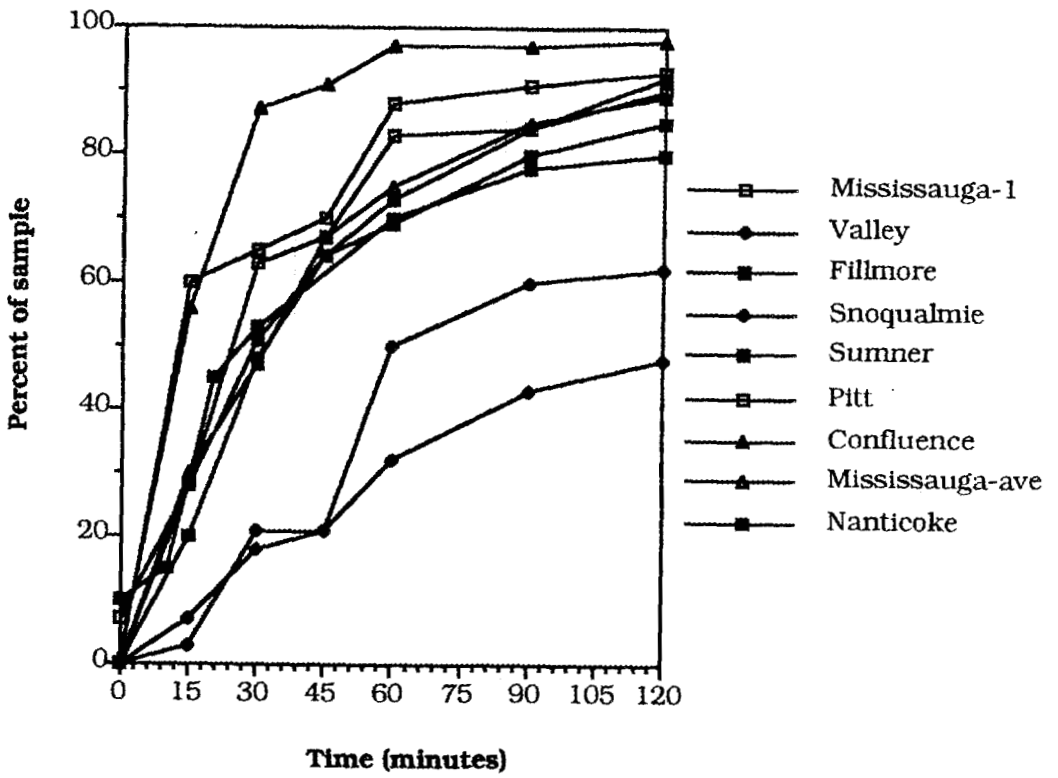


Fig. 4. Mobilization time in selected events.

3. CONCLUSIONS

3.1 Introduction

Issues raised by the documents reviewed indicate that emergency planning flexible enough to accommodate a range of scenarios should be incorporated into every emergency plan. In an emergency, it is easy to make decisions when relevant information is known, but how and when to transmit information to a threatened public or personnel in the field to facilitate the proper public response is still a major planning issue. Handling a crisis is easier when communication with all response organizations has been established prior to an event. Interjurisdictional and interagency cooperation is fostered when warning systems are developed for common hazards such as flooding, hurricanes, or transportation accidents. Other key strategies in emergency management include knowing what factors indicate that evacuation is preferred over sheltering and knowing the social characteristics and locations of threatened populations, whether dispersed or concentrated. Providing adequate warnings can generally elicit the preferred response from the public. Information on timing of evacuation, and eventually on the recommended time of return, is also critical to facilitating an effective evacuation. The question of providing sufficiently for evacuees of all ages and physical conditions at mass-care shelters has also surfaced as an emergency-planning issue.

3.1.1 Status of Current Research

Overall, the amount of empirical data on human behavior during evacuations for natural and technological accidents has increased only slightly. The one exception is for hazardous-materials incidents. We now have data sets on an additional six evacuations, based on post-event surveys (Duclos et al. 1987, 1989; Baron et al. 1988; Rogers and Sorensen 1989). The findings considerably extend our knowledge of evacuation behavior, especially for fast-moving events.

For natural hazards, few empirical studies have been completed that contribute to the data base. Specific contributions by Nelson et al. (1988, 1989) on hurricane evacuation behavior, and by Baker (1987) on Hurricane Kate and Elena warning response, have confirmed prior notions of evacuation behavior. The hurricane evacuation behavior research provides the first known empirical data that confirm the general social science proposition that behavioral intent studies on disaster responses

are not indicative of actual human behavior (Nelson et al. 1989). The study found little corroboration between expressed intentions derived from pre-hurricane surveys and actual evacuation behavior derived from post-event surveys. Many planning strategies are driven by behavioral intent studies, so this finding is significant in suggesting that the basis for planning may be critically weak in some areas.

The amount of information about how long it takes to disseminate a warning and how much time people spend responding to the warning has increased considerably. Through empirical measurement and modeling, we are beginning to understand how different warning technologies affect dissemination and how long people take to mobilize. We still cannot explain individual variations in evacuation departure times. Many of the findings on mobilization times have been incorporated into transportation and evacuation simulation models, resulting in more sophisticated quantitative evacuation time estimate models; however, the models still lack validation across hazards and verification with empirical data.

There have been significant improvements in the content of information in public warnings. This has been particularly true for multiple-threat situations and events with long lead times, such as hurricanes. Warnings now have better visual presentation, with more sensitive treatment of emergency measures. Still, little is known on how specific segments of the general population respond to variations in the content of a warning message or different styles of information presentation. The more specific the warning, the greater the compliance with the warning messages.

Since the Chernobyl accident and the implementation of SARA Title III, there has been more concern over designated EPZs. Although the Chernobyl experience generated considerable data on exposure levels and effective measures to protect the populations exposed, it also raised genuine concern over dispersion plumes and the protection that would be required in other catastrophic events. The concern is reflected not just in the nuclear power industry but in a variety of hazardous situations to which evacuation planning applies. Models of dispersion of toxic or other chemical substances have become more attuned to geographical and atmospheric effects and to the behavioral factors that influence protective actions. The knowledge that worst case scenarios are not intractable has forced emergency planning into the political foreground in many communities.

Another finding is the current lack of research on permanent relocation or on crisis relocation for nuclear war. The public belief that the worst case evacuation scenarios for nuclear power plant accidents should include permanent as opposed to temporary relocation has been reinforced by the Chernobyl disaster. However, to our

knowledge, no theoretical or empirical work discussing the possibility of such relocation within the United States has been accomplished.

3.2 Integration of Research Findings

In the previous work, we had not integrated the findings from the research on building evacuations caused by fire. Fire research findings complement other evacuation findings because the conclusions are very consistent with findings from disaster research, providing greater confidence in the findings on natural and technological hazards. One major conclusion is that people are more likely to take familiar routes in evacuating, a finding consistent with that of the disaster literature. That people retain work-related roles, provide helpful behavior, and do not panic when faced with evacuating from hazards from which there is a reasonable chance of escape are three other conclusions supported by both sets of evidence.

In general, our ability to predict human evacuation behavior has increased. A general finding within both the theoretical and empirical literature gives certain macro-level variables—such as type of threat, the SES composition of the population, and warning times—greater reliability in determining public response to emergencies. Focusing on these variables has improved our knowledge about how certain patterns of behavior emerge within a population faced with an evacuation directive. For example, we are now fairly certain that populations adjust the timing of their responses to the speed of the onset of a threat. Another finding suggests that levels of family resources affect evacuation response, especially in choice of shelters.

We also have more information on the evacuation needs of special groups—both institutional ones (nursing homes, hospitals, and schools) and specialized segments of populations, such as minority groups. The findings need further validation through the examination of a wider range of institutions and other special groups dispersed throughout the population, such as the hearing or visually impaired. Some experimental research on fire safety suggests that basic training in fire drills can induce correct responses to fires for mentally impaired persons. More attention should be given to groups that converge or are located temporarily in places not generally considered for mass evacuations. Having greater-than-average-size crowds evacuate a building or site designed for normal occupancy can invalidate prior evacuation strategies in an emergency. Tragic results have occurred when a crowd's actions, such as those that have occurred in stadiums or at concerts, have overwhelmed security strategies to manage egress behavior.

3.3 Future Directions

There are several trends evident from our analysis of the evacuation literature. The trends in research agenda indicate that the hazards addressed tend to be technological in nature or those that affect large segments of populations, such as hurricanes or earthquakes. Furthermore, most of the recent analyses concerning natural hazards have centered on the synthesis of previous findings or studies and the general search for behavioral patterns. There have been few attempts to provide new empirical data or to expand on an earlier study with new data.

A problem for synthesis is the lack of comparability of data sources. Most surveys contain unique questions. Even when a similar concept is measured, a difference in the question or coding can hinder precise comparison. The same is true for census-type data bases. Binder (1989) examined three data sets to determine how they reported similar transportation events and found few similarities.

We also detect a trend for closer examination of the psychological consequences of evacuations to determine how the stress from an event affects subsequent evacuation behavior. Unlike most previous research on evacuation behavior, which downplayed psychological impacts, studies now accept elevated stress among victims and emergency responders as contributing factors influencing human behavior during evacuations. Current trends include debriefing first responders and other emergency-care workers after an event and establishing outreach centers to help victims cope with the aftereffects of a traumatic event.

There has also been a trend toward increased public awareness of chronic environmental threats within communities. Probably the greatest change in community knowledge bases for planning, including designing strategies for protective actions, was promulgated by the community right-to-know clause of SARA Title III. Under SARA Title III, local governments must establish a commission to plan for industrial risk and crisis responses. Although the law is vague on criteria as well as expected outcomes, SARA Title III resulted in disclosures by industries of the amounts of toxic chemicals emitted into communities. Kartez (1989) suggests that the known presence of a toxic chemical threat increases group activation and leads to broader Title III participation, a trend that may become apparent in states with major chemical industries, such as New York (Abrams 1986). Like other issues of public concern, a law protecting populations from such hazards will take years to be legislated and accomplish such an objective.

Above all, there is an evident trend for increased professionalism within the field of emergency management. The trend has been noticeable in all the emergency-related fields, both in practical guidance and application of research findings. The increased professionalism has been helped by the influx of personal computers, allowing training through computerized simulations. Furthermore, there has been a proliferation of trade journals and manuals during the last few years that focus on emergency management. Other related issues, including liability and current regulatory changes, have promoted a broader understanding of the complex topics in emergency response.

A trend toward increased conservatism within communities in handling emergency response is also noticeable, particularly where hazardous materials or chemical accidents are involved. Evacuations have become more a precautionary procedure rather than an actual protective action. Officials appear reluctant to advocate sheltering or other protective actions when confronted with emergencies involving the public.

It is evident from this study that we are experiencing a steady progression of knowledge about human behavior in evacuations and evacuation planning. It is also safe to conclude that no revolutionary new discoveries have been made. In some areas, the research is characterized by new insights on fairly specific issues, such as panic, but there have been no new research findings that significantly challenge existing paradigms in disaster research.

4. REFERENCES

23 NRC 294 1986. Atomic Safety and Licensing Board in the Matter of Carolina Power and Light Company, (NRC Docket No. 50-400-0L).

Abrams, R. 1986. *Report on the Toxic Chemical Accident at the FMC Corporation, Middleport, New York on November 15, 1984: A Case Study in Prevention, Emergency Response and Reform.*, Environmental Protection Office, Office of the Attorney General, New York.

Aghababian, R. V. 1986. "Hospital Disaster Planning," *Topics in Emergency Medicine* **7**(4): 46–54.

Archea, J. 1979. *The Evacuation of Non-ambulatory Patients From Hospital and Nursing Home Fires: A Framework for a Model*, National Bureau of Standards, U.S. Department of Commerce, Washington, DC.

Assouline, M., et al 1987. "Economic Consequences of Evacuation in Industrialised Urban Areas," *Radiation Protection Dosimetry* **21**(1/3): 165–169.

Auf der Heide, E. 1989. *Disaster Response: Principles of Preparation and Coordination*, The C. V. Mosby Co., St. Louis.

Babineau, A. J. 1989. "Fire Safety for Emergency Evacuation Centres," *Emergency Preparedness Digest* **16**(3): 18–19.

Baker, J. 1987. *Warning and Evacuation in Hurricanes Elena and Kate*, Department of Geography, Florida State University, Sea Grant Project # IR-85-11, Tallahassee, Fla.

Banz, G., and R. T. Newkirk 1987. "The Roles of Computer Simulation in Emergency Planning," *Emergency Preparedness Digest* 14(4): 22–24.

Baron, R. C., R. A. Etzel, and L. M. Sanderson 1988. "Surveillance for Adverse Health Effects Following a Chemical Release in West Virginia," *Disasters* **12**(4): 356–365.

Bastien, M. C., et al. 1985. "Evacuation Risks: A Tentative Approach for Quantification," *Risk Analysis* **5**(1): 53–61.

Bellamy, L. 1986. *Review of Evacuation Data, Final Report,* Technica Consulting Scientists and Engineers, London.

Bellamy, L. J., and P. I. Harrison 1988. "An Evacuation Model for Major Accidents," unpublished paper presented at conference, *Disasters and Emergencies: The Need for Planning,* Organized by IBC Technical Services Ltd., London, April 12-13.

Berke, P., and N. Stubbs 1989. "Automated Decision Support Systems for Hurricane Mitigation Planning," *Simulation* **53**(3): 101–109.

Binder, S. 1989. "Deaths, Injuries, and Evacuations from Acute Hazardous Materials Releases," *American Journal Public Health* **79**(8): 1042–1044.

Bloomquist, L., R. Hanninen, and A. P. Vuorinen 1986. "Emergency Planning by the Public Authorities in Finland," pp. 13-26 in *Emergency Planning and Preparedness for Nuclear Facilities,* Proceedings of a Symposium Rome, November 4-8, 1985. IAEA, Vienna.

Bolin, R. 1986. *The 1986 California Floods. Quick Response Research Report #02,* University of Colorado, Institute of Behavioral Science, Boulder, Colo.

Bolton, P. 1987. *Final Report on the Evaluation of Three Earthquake Prediction Projects,* Battelle Memorial Institute's Pacific Northwest Laboratory, Seattle.

Breznitz, S. 1984. *Cry Wolf: The Psychology of False Alarm,* L. Earlbaum, Hillsdale, N.J.

Brown, P. 1987. "Popular Epidemiology: Community Response to Toxic-Induced Disease in Woburn Massachusetts," *Science, Technology and Human Values* **12**(3&4): 78–85.

Brown, S. T., et al. 1988. "Sheltering and Response to Evacuation During Hurricane Elena," *Journal of Emergency Nursing* **14**(1), Jan/Feb: 23–26.

Bryan, J. L. 1982. "Human Behavior in The MGM Hotel Fire," *Fire Journal* **76**: 37–48.

Buck, W. B. 1987. "Environmental Pollution, Including Toxic Wastes," *Journal of the American Veterinary Medical Association* **190**(6): 793–796.

Cann, M. 1990. "Hagersville!" *Emergency Preparedness Digest* **17**(2): 2–7.

Clarke, J. I., et al. (eds.) 1989. *Population and Disasters*, Basil Blackwell, Inc., Oxford, U.K.

Duclos, P., et al. 1987. "Community Evacuation Following a Chlorine Release, Mississippi," *Disasters* **11**(4): 286–289.

Duclos, P., S. Binder, and R. Riester 1989. "Community Evacuation Following the Spencer Metal Processing Plant Fire, Nanticoke, Pennsylvania," *Journal of Hazardous Materials* **22**:1–11.

Dudley, W., and M. Lee 1988. *Tsunami*, University of Hawaii Press, Honolulu.

Envirosphere 1983. *Detailed Report on the Evacuation of December 11, 1983*, Report prepared for Louisiana Power and Light Company.

Faupel, C. E., C. Bailey, and M. Williams 1987. *Hazardous Waste and Emergency Planning: A Case Study of Sumter County, Alabama*, Bulletin 587, Alabama Agricultural Experimental Station, Auburn University, Auburn, Ala.

FEMA (Federal Emergency Management Agency) 1989. *Hazardous Materials Exercise Evaluation Methodology (HM-EEM) and Manual.*, FEMA, Washington, DC.

Fischer, H. W. 1989. "Hurricane Gilbert: The Media's Creation of the Storm of the Century," Natural Hazards Research and Applications Information Center, Institute of Behavioral Science, University of Colorado, Boulder, Colo.

Floren, T. M. 1987. "Miamisburg: The Financial Reckoning," *Fire Command* (Oct): 33–41.

GAO (U.S. Government Accounting Office) 1987. *Nuclear Regulation: Public Knowledge of Radiological Emergency Procedures*, (GAO/RCED-87-122), U.S. GAO, Washington D.C.

Garten, R. H., and E. R. Russell 1985. "Integration of Hazardous Materials Emergency Planning into Small-town Planning Process," pp. 74–78 in *Recent Advances in Hazardous Materials Transportation Research: An International Exchange*, papers presented at conference by Transportation Research Board, November 10-13, 1985, Transportation Research Board National Research Council, Washington, D.C.

Geyer, T. A., et al. 1988. "An Evaluation of the Effectiveness of the Components of Informative Fire Warning Systems," unpublished paper, International Conference on Safety in the Built Environment, July 13-15, Central Library, Guildhall Square, Portsmouth, England.

Glickman, T., and A. M. Ujihara 1990. "Deciding Between In-place Protection and Evacuation in Toxic Vapor Cloud Emergencies," *Journal of Hazardous Materials* **23**: 57–72.

Golding, D., and R. J. Kasperson 1988. "Emergency Planning and Nuclear Power: Looking for the Next Accident," *Land Use Policy* **5**(1): 19–36, Center for Technology, Environment, and Development, Clark University.

Graham, J. K. "Hurricane Evacuation Studies: An Overview," *Coastal Zone 1989*, Baltimore, 820–829.

Gray, J., and E. L. Quarantelli 1985. "First Responders and Their Initial Behavior in Hazardous Chemical Transportation Accidents," pp. 97–104 in *Recent Advances in Hazardous Materials Transportation Research: An International Exchange*, papers presented at conference by Transportation Research Board, November 10-13, 1985, Transportation Research Board National Research Council, Washington, D.C.

Green, M. D. 1989. "When Toxic Worlds Collide: Regulatory and Common Law Prescriptions for Risk Communication," *Harvard Environmental Law Review* **13**(1): 209–243.

Grice, G., R. Sheets, and D. Perry 1989. "Hurricane Gilbert: The Issue of Conflicting Information," Panel Session at the *Natural Hazard Workshop*, July 17, 1989, Boulder, Colo.

Gruntfest, E., and C. Huber 1989. "Status Report on Flood Warning Systems in the United States," *Environmental Management* **13**(3): 279–286.

Haney, J. I., and R. T. Jones 1982. "Programming Maintenance as a Major Component of a Community-Centered Preventive Effort: Escape from Fire," *Behavior Therapy* 13: 47–82.

Hargest, T. S. 1982. "Emergency Hospital Evacuation Plans: How Adequate Are They?" *Medical Instrumentation* **16**(3), May-June: 174–175.

Harper, S. T. 1989. "LEPCs and Title 111," *Hazmat World* **2**(9): 57–61.

Harrison, P. I., and L. J. Bellamy 1988. "Modeling the Evacuation of the Public in the Event of Toxic Releases: A Decision Support Tool and Aid for Emergency Planning," pp. 241–255 in *Human Factors and Decision Making: Their Influence on Safety and Reliability*, B.A. Sayers, ed., Elsevier Applied Science, London.

Henry, S. 1980. "Mississauga Hospital: Largest Evacuation in Canada's History," *CMA (Canadian Medical Association) Journal* 122 (March): 582, 585–586.

Hillsman, E. L., and P. R. Coleman 1989. "Integrating Demographic, Atmospheric, and Dose Information to Estimate Effects from Accidental Release of Chemical Agents," *The Environmental Professional* **11**(4): 354–366.

Hobeika, A. G., B. Jamei, and I. B. Santoso 1985. "Selection of Preferred Highway Routes for the Shipment of Spent Nuclear Fuel Between Surry and North Anna Power Stations in Virginia," pp. 67–73 in *Recent Advances in Hazardous Materials Transportation Research: An International Exchange*, papers presented at conference by Transportation Research Board, November 10-13, 1985, Transportation Research Board National Research Council, Washington, D.C.

Horiuchi, S., Y. Murozaki, and A. Hokugo 1986. "A Case Study of Fire and Evacuation in a Multi-purpose Office Building, Osaka, Japan," pp. 523–532 in *Fire Safety Science-Proceedings of the First international Symposium.*, C. Grant, and P.J. Pagni, eds., Hemisphere Publishing Corp., Washington, D.C.

Hushon, J., R. B. Kelly, and C. Rubin 1989. "Identification and Analysis of Factors Affecting Emergency Evacuations," report prepared for the Nuclear Management and Resources Council, Inc., Washington, D.C.

Jacobs, B. D., and P. 't Hart (no date) "Disaster at Hillsborough Stadium: A Comparative Analysis," unpublished paper.

Johnson, J. H., and D. J. Zeigler 1989. "Nuclear Protective Action Advisories: A Policy Analysis and Evaluation," *Growth and Change* **20**(4) Fall: 51–65.

Johnson, D. M., and N. R. Johnson 1989. "Role Extension in Disaster: Employee Behavior at The Beverly Hills Supper Club Fire," *Sociological Focus* **22**(1): 39–51.

Jones, R. T., A. E. Kazdin, and J. L. Haney 1981. "Social Validation and Training of Emergency Fire Safety Skills for Potential Injury Prevention and Life Saving," *Journal of Applied Behavior Analysis* **14**(3): 249–260.

Kagawa, M., S. Kose, and Y. Morishita 1986. "Movement of People on Stairs During Fire Evacuation Drill—Japanese Experience in a Highrise Office Building," pp. 533–540 in *Fire Safety Science-Proceedings of the First international Symposium.*, C. Grant, and P.J. Pagni, eds., Hemisphere Publishing Corp., Washington, D.C.

Kartez, J. 1989. "Community Planning for Industrial Risk: A Title III Agenda," *Industrial Crisis Quarterly* **3**(1): 61–76.

Kartez, J. D. and M. L. Lindell 1987. "Planning for Uncertainty," *Journal of the American Planning Association* **53**(4): 489–498.

Kartez, J. D., and M. L. Lindell 1990. "Adaptive Planning for Community Disaster Response," pp. 5–31 in *Cities and Disaster: North American Studies in Emergency Management.*, R. T. Sylves, and W.L. Waugh, eds., Charles C. Thomas, Springfield, Ill.

Khisty, C. J. 1985. "Pedestrian Flow Characteristics on Stairways During Disaster Evacuation," *Transportation Research Record* **1047**: 97–102.

Klein, B. R. 1987. "Evacuation and The Resistive Patient," *Fire Command* (Feb.): 32 and 48.

Koch, J., and J. Tadmor 1988. "Sheltering—A Protective Measure Following An Accidental Atmospheric Release from a Nuclear Power Plant," *Health Physics* **54**(6) June: 659–667.

Ledingham, J., and L. M. Walters 1989. "The Sound and The Fury: Mass Media and Hurricanes," in *Bad Tidings: Communication and Catastrophe*, L. M. Walters, L. Wilkins, and T. Walters, eds., Lawrence Erlbaum Associates, Hillsdale, N.J.

Levin, B. M. (ed.) 1980. *Fire and Life Safety for the Handicapped: Conference and Preparatory Workshop Reports*, National Bureau of Standards, Department of Commerce, Washington, D.C.

Lichtenberg, J., and D. MacLean 1988. "The Role of the Media in Risk Communications," pp. 33–48 in *Risk Communications: Proceedings of the International Workshop on Risk Communications*, H. Jungermann, et al. eds., Kernforschungsanlange, Julich, France.

Lindell, M., and R. Perry 1987. "Warning Mechanisms in Emergency Response Systems," *Int. J. of Mass Emergencies and Disasters* **5**(2): 137–153.

Lowenhardt, J., and G. P. van den Berg 1989. "Disaster at Chernobyl Nuclear Power Plant: A Study of Crisis Decision Making in the Soviet Union," pp. 37–65 in *Coping With Crises: The Management of Disasters, Riots and Terrorism.*, U. Rosenthal, P. 't Hart, and M.T. Charles, eds., Charles C. Thomas, Springfield, Ill.

Martin, J. A., and T. J. McKenna. 1988. "NRC Perspectives on Protective Action Decisionmaking for an Emergency at a Nuclear Power Plant," Paper presented at the *Proceedings of the ANS Topical Meeting on Emergency Response—Planning, Technologies, and Implementation*, Sept. 26-28, Charleston, S.C.

Menker, R. E. , and T. M. Floren 1986. "White Phosphorus Ignites in the Miamisburg Derailment," *Fire Command* (Oct): 30–34, 41.

Mileti, D., J. Sorensen, and W. Bogard 1985. *Evacuation Decision-making: Process and Uncertainty*, ORNL/TM-9692, Oak Ridge National Laboratory, Oak, Ridge, Tenn.

Mileti, D., and J. Sorensen 1988. "Planning and Implementing Warning Systems," pp. 321–345 in *Mental Health Response to Mass Emergencies, Theory and Practice*, M. Lystad, ed., Bruner/Mazel Pub., New York.

National Institute of Mental Health 1986. *Disasters and Mental Health*, American Psychiatric Press, Inc., Washington, D.C.

Nehnevajsa, J. 1990. *Emergency Preparedness: Reports and Reflections of Local and County Emergency Managers*, Final Report for Federal Emergency Management Agency, University Center for Social and Urban Research, University of Pittsburgh, Pittsburgh.

Nelson. C. E., A. Kurtz, and G. Hacker 1988. "Hurricane Evacuation Behavior: Lessons from Elena," *Public Affairs Reporter* **2**(2) Fall.

Nelson, C. E., et al. 1988. *Post-Hurricane Behavior of Evacuees in the Tampa Bay Region During Hurricane Elena in 1985*, unpublished paper, University of South Florida, Tallahassee, Fla.

Nelson, C. E., et al. 1989. *Lower Southwest Florida Hurricane Study*. University of South Florida, Tampa, Fla., or U.S. Army Corps of Engineers, Jacksonville District Office, Jacksonville, Fla.

Nelson, C. E., et al. 1989. *Models of Hurricane Behavior*, University of South Florida, Tampa, Fla.

Nober, I. H, A. D. Well, and S. Moss 1990. "Smoke Alarms for the Hearing Impaired," *Fire Journal* Jan/Feb.: 26–30.

Orchard, H. C. 1988. "What Chernobyl Has Taught Us About Emergency Planning," *Journal of Radiological Protection* **8**(1): 51–54.

Pauls, J. 1984. "The Movement of People in Buildings and Design of Solutions for Means of Egress," *Fire Technology* **20**(1): 27–47.

Pauls, J. 1987. "Calculating Evacuation Times for Tall Buildings," *Fire Safety Journal* **12**(3): 213–236.

Perry, R. W. 1987. "Disaster Preparedness and Response Among Minority Citizens," pp. 135–151 in *Sociology of Disasters*. R.R. Dynes, B. DeMarch, and C. Pelanda, eds., Franco Angeli, Milano, Italy.

Perry, R. W., and A. H. Mushkatel 1986. *Minority Citizens in Disasters*, University of Georgia Press, Athens, Ga.

Quarantelli, E. L. 1980. *Evacuation Behavior and Problems: Findings and Implications From the Research Literature*, Disaster Research Center, Ohio State University, Columbus, Ohio.

Rogers, G. O., and J. H. Sorensen 1989. "Warning and Response in Two Hazardous Materials Transportation Accidents in the U.S.," *Journal of Hazardous Materials* **22**: 57–74.

Rosenthal, U., M. T. Charles, and P. 't Hart (eds.) 1989. *Coping with Crises: The Management of Disasters, Riots and Terrorism.*, Charles C. Thomas, Springfield, Ill.

Sato, H., and T. Ouchi 1986. "Computer Simulations for Total Firesafety Design of the New Japanese Sumo Wrestling Headquarters and Stadium (Kokugikan)," pp. 541–550 in *Fire Safety Science-Proceedings of the First International Symposium*, C. Grant, and P.J. Pagni, eds., Hemisphere Publishing Corp., Washington, D.C.

Scanlon, J. 1990. "Political Leadership and Canadian Emergency Planning: the Role of the Mayor," pp. 165–181 in *Cities and Disaster: North American Studies in Emergency Management*, R. T. Sylves, and W. L. Waugh, eds., Charles C. Thomas, Springfield, Ill.

Schneider EC Planning and Management Services 1987. "Report of the Evacuation of Nanticoke, Pennsylvania, March 24, 1987," prepared for the Pennsylvania Power and Light Company.

Smith, V. K., W. H. Desvousges, A. Fisher, and F. R. Johnson 1988. "Learning About Radon's Risk," *Journal of Risk and Uncertainty* 1: 233–258.

Sorensen, J. H. 1986a. "Evacuation Behavior in Nuclear Power Plant Emergencies: An Alternative Perspective," pp. 351–356 in *Proceedings of the American Nuclear Society (ANS) Topical Meeting on Radiological Accidents: Perspectives and Emergency Planning*, Bethesda, Md., September 15.

Sorensen, J. H. 1986b. "Evacuations Due to Off-site Releases from Chemical Accidents: Experience from 1980 to 1984," *Journal of Hazardous Materials* **14**(2): 247–257.

Sorensen, J. H. 1987. "Warning Systems in the 1985 Cheyenne Flash Flood," pp. 174–183 in *What We Have Learned Since the Big Thompson Flood, Proceedings of the Tenth Anniversary Conference*, E. Gruntfest, ed., July 17-19, Natural Hazards Research and Applications Information Center, University of Colorado, Boulder, Colo.

Sorensen, J. H., and D. Mileti 1987. "Decision-making Uncertainties in Emergency Warning System Organizations," *International Journal of Mass Emergencies*, **5**(1): 33–61.

Sorensen, J. H., and G. O. Rogers 1988. "Community Preparedness for Chemical Emergencies: A Survey of U.S. Communities," *Industrial Crisis Quarterly*, **2**(2), 89–108.

Sorensen, J. H., G. O. Rogers, and W. F. Clevenger 1988. *Review of Public Alert Systems for Emergencies at Fixed Chemical Facilities*, ORNL/TM-10825, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Sorensen, J. H., and D. Mileti 1989. "Warning Systems for Nuclear Power Plant Emergencies," *Nuclear Safety* **30**(3): 358–370.

Southworth, F., and S. M. Chin 1987. "Network Modelling for Flooding as a Result of Dam Failure," *Environment and Planning* **19**: 1543–1558.

Southworth, F. and S. M. Chin 1987. *Quantifying Spontaneous Evacuation in Time of Threat: A Near Real Time Traffic Monitoring System for the Tampa Bay Area*, DE-AC05-84OR21400, Oak Ridge National Laboratory, Oak Ridge, Tenn.

DOT, EPA, and FEMA 1987. *Technical Guidance for Hazard Analysis*, Washington, DC.

Vogt, B. M., and J. H. Sorensen 1987. *Evacuation in Emergencies: An Annotated Guide to Research*, ORNL/TM-10277, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Vogt, B. M. 1990. *Evacuation of Institutionalized and Specialized Populations*, DE-AC05-84OR21400, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Vogt, B. M. 1991. *Evacuation in Emergencies: An Annotated Bibliography*, University of Tennessee, Energey Environment and Resources Center, Knoxville, Tenn.

Witzig, W. F., and J. K. Shillenn 1987. *Evaluation of Protective Action Risks*, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C.

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